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PREFACE

Although the Southern Forage and Pasture Crop Improvement Conference (SPFCIC) is an outgrowth of an American Society of Agronomy meeting in New Orleans in 1939, it has become a multi-disciplinary organization over these past 50 years. The organization now encompasses the specializations of Plant Breeding, Ecology, Plant Physiology, Extension (both Animal and Plant), Forage Utilization involving Crop Scientists and Animal and Dairy Scientists. These scientists are in Universities, State Experiment Stations, and ARS-USDA. It is with the guidance, wisdom, and expertise of the multitude of scientists that the SPFCIC should have a continued long era of productivity in area of forages.

These proceedings include the papers and reports of the 45th SPFCIC. These proceedings address the opportunities and challenges in forage/livestock production and research. The papers and business meeting minutes for the forage breeding, forage utilization, forage ecology/physiology and forage extension work groups are presented in this publication, along with the minutes of the business meeting and executive committee meeting.

A special thanks is expressed to the University of Arkansas Cooperative Extension Service personnel who spent many hours of time and effort in hosting an outstanding conference.

H. Werner Essig
Chairman, 45th SPFCIC

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K.K. BOLSEN

SUMMARY

The seasonal supply of nutrients from grasslands and harvested forages make conservation essential for year-round ruminant livestock production. The biological principles of hay-making and silage-making and appropriate management practices and technologies, combine to make highly efficient forage preservation possible. However, there is a large gap between what can be achieved in theory and what is actually achieved on many farms today.

There are too many failures in hay conservation. Field losses from respiration, mechanical treatment, and leaching and subsequent storage losses can exceed 50% of the crop. Hay-making must become less dependent on the uncontrollable factor, weather. This might be achieved by increasing the drying rate with chemicals or improving the efficiency of mechanical treatments. Preservatives could also minimize the weather risks by allowing hay to be baled at higher moistures.

Since the early 1950's, there has been a steady increase in the percentage of forage conserved as silage. Success in silage-making depends on the suitability of the crop and the technology (management and know-how) used by the farmer. Quickly achieving anaerobic conditions in the silo is essential if in-silo losses are to be minimized. The use of inoculants and chemical additives can reduce the risks of poor fermentation.

The efficiency of forage conservation-feeding systems is determined as animal product/ha (APH). Only a few studies have measured both of the necessary components--nutritive value of the forage and net forage yield after conservation. These results indicate that APH is affected more by management practices within a system (hay or silage) than by differences between systems (hay versus silage).

KEY WORDS: forage, conservation, nutritive value, hay, silage, fermentation, losses.

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INTRODUCTION

The supply of nutrients from grasslands and harvested forages is seasonal in most of the world because of either low temperatures or drought. Thus, the conservation of harvested forages becomes an essential part of ruminant livestock feeding systems. The principles of drying (hay) and fermentation (silage) have been used for thousands of years by farmers to conserve feed. To achieve satisfactory preservation, it is necessary to minimize respiration and proteolysis by plant enzymes and also to minimize microbial degradation during the harvest and storage periods. Zimmer (1983) stated there are no other principles of conservation practiceable for agriculture purposes.

Conservation involves change in the physical and/or chemical composition of the forage, as well as loss of nutrients in the field and in storage. These changes affect the nutrient availability, intake characteristics, and animal production from the forage. With well-preserved silage made from forages grown in temperate climates, live-weight gains by growing cattle of .9 to 1.2 kg/day and milk productions of 18 to 24 kg/day at peak lactation are possible--much higher than the animal performance obtained from silage or hay on most farms today. This review looks at

existing conservation - feeding practices for temperate forages and identifies weaknesses in those practices that limit conservation efficiency, nutritive value, and animal production.

CONSERVATION BY HAY-MAKING

The objective of hay-making is to achieve a rapid moisture loss after cutting so the forage can be removed from the field with minimum losses from weathering and microbial degradation. The degree of success (or failure) in hay-field operations also has a tremendous affect on the storage characteristics of the hay and the proportion of original forage nutrients available for feeding.

The rate at which a forage dries in the field depends primarily on vapor pressure differences between the ambient air and the swath environment and forage tissue characteristics. Thus, water loss is rapid initially but slows as drying progresses. Three-fourths of the water may be lost in the first one-fifth of the drying time, with the final drying rate being less than one-hundredth of the initial rate. Conditioning equipment that abraids, crushes, or lacerates the forage has been used for many years to reduce crop resistance to water loss. Klinner (1982) reported that drying rate increased 50% with a steel spoke conditioner and 135% with co-rotating twin brush plastic elements. Swath dimensions, structure and density, and frequency and method of tedding and turning affect the water content and its location within the swath. Physical redistribution of the forage in the swath is more beneficial to drying rate when dry matter (DM) is below 70%, rather than above (Jones and Harris, 1980). Many studies have shown large differences in drying rate among grass species, with leaf:stem ratio accounting for a significant amount of this variation. Chemical desiccants have been more effective under laboratory conditions than in the field. A commonly used desiccant, potassium carbonate, has given inconsistent drying rates on various hay crops (Tullberg and Minson, 1978; Thomas et al., 1983). Unfortunately, this chemical does not speed the drying rate of grass.

The field losses associated with hay-making can be divided into three categories: 1) respiratory, 2) mechanical, and 3) leaching. Respiratory loss is influenced mainly by ambient temperature and forage dry matter. Honig (1980) found that respiration intensity decreased quadratically with increasing forage DM and increasing ambient temperature. In grass of 30% DM, respiration losses were .23 and .10% of the DM per hour at 15 and 30° C, respectively, but these losses dropped to only .05 and .02% in 60% DM grass. During field drying in daylight, some of the respiration loss is offset by the photosynthetic activity of the forage. However, this compensation is likely insignificant compared to field loss.

Mechanical loss represents forage not picked up during the harvesting operation. It increases with the degree of fragmentation during mowing or conditioning, tedding (turning), final windrowing, and loading. In contrast to respiration losses, fragmentation is most severe during the final stages of drying. Honig (1980) found that in grass the DM loss for each turning of the crop increased nearly 12 fold as moisture content declined from 75 to 20 percent. The wide variation observed at any individual crop moisture was likely due to the setting and speed of the machine, number of turnings, and type of forage. These losses were independent of yield, which meant that percentage values for mechanical losses decreased with increasing yield. Loading loss is also affected by the setting and ground speed of the pickup machine (baler). Normally, mechanical losses are higher for legumes than grasses because with legumes the leaf dries faster than the stem, resulting in greater leaf shattering. In a series of experiments, Klinner (1976) reported field DM losses averaged 39%

for alfalfa (Medicago sativa L.) and 19% for grass. Friesen (1978) reported leaf losses in alfalfa of 10 and 20% when baling at 35 and 20% moisture, respectively, and Arledge (1984) showed that the leaf:stem ratio of alfalfa hay changed from 58:42 to 42:58 when moisture content at baling changed from 25 to 15 percent.

Rainfall during the field drying period not only prolongs the drying time but also results in a direct loss of soluble nutrients through leaching. The extent of leaching loss is influenced by several factors including forage moisture content at the start of rainfall, amount of rainfall, number of rains, and mowing or conditioning treatments. Moller and Skovborg (1971) found with unconditioned grass cut with a reciprocating mower that 20 mm of artificial rain over a 24-hour period resulted in a DM loss which increased from 1% for grass with 80% moisture at the start of leaching to over 8% when the grass was 26% moisture at the start. Collins (1982) found that legume species differed in their response to rainfall during field drying and that the initial wetting increased the susceptibility of the forage to leaching during subsequent wettings. When drying conditions were favorable, unwetted alfalfa had an average DM loss of 8.5% compared with 14.0% for wetted hay. However, during unfavorable drying conditions, wetting resulted in an average DM yield loss of 43.3 percent.

There have been several estimates of total field losses during hay-making in recent years (Klinner 1976; Marten, 1980) and all stress two common points. First, weather is the most important factor influencing drying losses. Second, the range of losses is wide, from 4 to 60% of the forage dry matter.

Losses during hay storage are caused by continued plant respiration, activity of microorganisms, and chemical oxidation. The magnitude of storage losses are also influenced by a multitude of factors including initial storage moisture, storage facility or site (barn, stack, plastic cover, etc.), artificial ventilation (drying), bale size and density, and length of storage. Results from a number of sources were summarized by Wilkinson (1981). His review indicated that losses were in the order of 3 to 7% of the DM entering storage, if accepted management practices were followed.

Large round bales of alfalfa had DM losses of 2 to 11% for outside storage, versus 1 to 7% for inside (barn) storage (Bell and Martz, 1981). These authors have reported losses up to 24 percent. Under the worst of circumstances, heat produced by continued plant respiration after baling, in the presence of sufficient hay moisture and oxygen, encourage thermophilic microbial activity, chemical oxidation of plant tissues, and spontaneous combustion.

Engineering advancements in the past decade have increased the use of high capacity hay-harvesting machines which produce larger hay packages. This equipment was attractive because it allowed hay-making and feeding to be a one man operation and it made long-distance transportation of hay more practical. But the storage and feeding losses from these packages have often far exceeded those of traditional hay systems (Kjelgaard et al., 1983).

Hay-making will always depend on the uncontrollable factor, weather. Little progress has occurred in this decade to reduce this dependency (Lingvall and Nilsson, 1980). However, preservatives could minimize this risk by allowing hay to be baled at higher moistures, thus reducing field and storage losses and increasing nutritive value. In many hay-making areas of the world, the forage is produced under irrigation in a climate of high temperature and low rainfall (Arledge, 1984). In such conditions, there are often only a few hours, usually in the early morning or late evening, when the forage is at an ideal baling moisture. Preservatives and moist hay could lengthen the hours

for optimum baling and reduce fragmentation from over-dried swaths. Propionic acid, ammonia, and urea are among the many chemicals which have successfully reduced field and storage losses in moist hay under research conditions (Knapp et al., 1976). But before any preservative will receive wide acceptance under farm conditions, uniform application (and retention) and hazardous handling problems must be solved.

The moisture levels for safe and efficient storage of hay are not well defined. Such factors as forage specie; bale type, size, and density; method of storage; and the time between baling and placing the hay in storage all affect the optimum storage moisture. And there continues the unsolved problem of determining, with speed and accuracy, the moisture of forage in the swath. Until this is overcome, the development of new technology in hay conservation will likely continue at a slow pace.

CONSERVATION BY SILAGE-MAKING

The objective of silage-making is to preserve the harvested crop by anaerobic fermentation. The technique has not changed appreciably during the past 100 years. The process involves converting soluble carbohydrates to lactic acid, which drops the pH to a level sufficient to inhibit any further biological activity in the ensiled forage mass. Our knowledge of the biochemistry and microbiology of silage fermentation has increased tremendously in the second half of this century, as evidenced by three comprehensive reviews (Watson and Nash, 1960; McDonald, 1981; Woolford, 1984).

Since the early 1950's in most developed countries, there has been a steady increase in both the total quantity of forage produced and the percentage of it conserved as silage. Reasons for the popularity of silage include: 1) it is much less weather dependent than hay-making, 2) it is more suitable than hay for large-scale livestock production, and 3) it is adaptable to a wider range of crops--ie. corn Zea mays L.), sorghum (Sorghum bicolor L.), and winter cereals. Despite our understanding of silage-making, silage quality remains on a plateau (Zimmer, 1983). Before examining this gap between available technologies for efficient conservation and the only "moderate" efficiency achieved on most farms, a closer look at the ensiling process is appropriate. The ensiling process is often described as one of minimizing nutrient losses and changes in nutrient value. In most circumstances, good silage is achieved by discouraging the activities of plant enzymes and undesirable microorganisms and encouraging the dominance of lactic acid bacteria. In the initial stages of ensiling, plant respiratory enzymes oxidize water soluble carbohydrates (WSC) resulting in heat production and decreasing sugars available for fermentation. Plant proteases hydrolyze proteins to amino acids and peptides. Bergen et al. (1974) reported that nonprotein nitrogen (NPN) increased from 20% of total nitrogen in pre-ensiled corn to 50% within 24 hours post-ensiling. Silages containing high amounts NPN usually do not support optimum animal production. The undesirable microorganisms are primarily clostridia, coliforms, and yeasts. They compete with lactic acid bacteria for WSC and many of their end products have no preservative action. The clostridia are responsible for secondary fermentation which can convert lactic acid to butyric acid and degrade amino acids to amines and ammonia. Clostridial silages have high nutrient losses, high NPN content, low digestibility, and low DM intake by the livestock. Yeasts are also linked to aerobic deterioration, particularly during the silage feedout period.

The ensiling process is influenced by a multitude of factors, either biological or technological (Fig. 1). Because many of these factors are interrelated, it is difficult to present their significance individually. However, there are two dominant features of every silage: the first is the nature

of the crop and the second is the technology (management and know-how) imposed by the farmer. If a stable silage pH is to be achieved without using additives, then chemical composition of the crop is of particular importance. The fermentable sugar or WSC content was used most often in earlier studies to predict the suitability of a crop for silage. After several attempts to correlate the ratio of sugar to crude protein, Wieringa (1962) concluded that a high ratio could produce both good and poor quality silage, but with a low ratio, silage quality would almost certainly be poor. Weissbach et al. (1974) provided a model to predict the fermentation pattern during ensiling from initial crop DM content and the ratio of WSC (Z) to buffer capacity (PK). This model was tested by Wilkinson et al. (1983) using 231 silages which represented a wide range of DM and Z/PK ratios. Their study partially confirmed the Weissbach model but much of the variation in crop composition and silage quality was still unaccounted for. When cluster analysis was used, the 231 silages formed seven distinct groups; three were good quality and four were poor. Variation in Z (as % of the fresh crop) appeared to be more important than variation in the other crop characteristics examined (DM, PK, Z/PK, and nitrogen). Only 5% of the silages made from crops with Z above 2% were of poor quality, whereas 44% of the silage made from crops with Z below 2% were of poor quality. Ohyama (1984) summarized a series of experiments and concluded that when crop DM was high enough, good silage was produced irrespective of WSC, but when DM and WSC were both low, the silage was usually poor. Corn has been regarded as the "near perfect" silage crop--its nutrient digestibility and DM yield/ha plateau during the dough to flint kernel stages and its DM is in an ideal range of 25 to 45% for 3 to 4 weeks during the harvest season. Sorghum is becoming an important crop in the USA and most cultivars have forage yields similar to corn. However, late-season sorghums are often ensiled at a low DM which results in high in-silo losses, low DM intake, and poor animal performance (Bolsen and Smith, 1984).

The control of silage fermentation within predictable boundaries at the farm level is clearly th biggest challenge to improving nutrient conservation and utilization. In contrast to large industrial fermentations, silage is made from a heterogeneous raw material (crop) of various suitabilities, with spontaneous fermentation by epiphytic microflora, and under varied environmental conditions. Major efforts have been made throughout the 20th century to control silage fermentation with additives. These were recently categorized and their effects on silage quality summarized (McDonald, 1981; Woolford, 1984). The use of chemicals such as formic or sulfuric acids to prevent clostridial fermentation and to achieve a satisfactory silage has been a common practice in many countries in Europe and Scandinavia. The value of such additives is clearly greatest in climates that make field-wilting difficult and with crops that are low in either DM or WSC content.

Presently there is renewed interest in the use of bacterial inoculants to improve the efficiency of the ensiling process. The epiphytic microflora on growing crops is usually high in strict aerobes and low in lactic acid bacteria. Rather than depend on the chance development of efficient bacteria to produce lactic acid, a logical approach is to use specific cultures which would dominate the ensiling process. Evidence suggests that mixed genera cultures are preferred over a single genus (Woolford, 1984). The selection of improved strains of lactic acid bacteria is now possible and the criteria which a potential organism should satisfy for use in silage were compiled by Whittenbury (1961). Other important properties include the ability to utilize polymers (ie. starch), no proteolytic activity, no

action upon organic acids, resistant to phages, active aerobically and anaerobically, good storage stability, and genetic stability. In addition, it may be possible through genetic engineering to improve promising strain characteristics, such as cellulose activity or action against yeasts. Inoculants are commercially available in most countries where silage-making is practiced. Their effect on silage quality has been reviewed by McDonald (1981) and Bolsen and Hinds (1984). Although much of the research data indicate a faster drop in pH and a more efficient homolactic fermentation, many past experiments with inoculants have given disappointing results. There are a number of possible reasons for these inconsistent responses. First, a high lactic acid bacteria population may have existed on the crop as it entered the silo. Second, the inoculation levels may have been too low to dominate the natural microflora. Third, the bacterial strains may not have been the most suitable for the crop or environmental conditions.

In the USA and Canada, where corn is the principle silage crop and alfalfa or grasses are easily wilted, inoculants and other fermentation aids have received fairly wide acceptance by farmers (Bolsen and Hinds, 1984; Bolsen and Heidker, 1985). Of the additives available today, inoculants appear to have the most inherent advantages to the user including low cost, safety in handling and application, low usage rate, and no residue problems. Further research is needed, particularly in selecting strains for specific crops and environmental conditions, before inoculants will receive widespread usage in all silage-making areas.

The DM losses from, silage-making can be divided into two categories: 1) unavoidable and 2) avoidable. Unavoidable include the loss in the field, plant respiration, and primary fermentation. Avoidable include effluent from the silo, secondary fermentation, and aerobic deterioration. Estimates of unavoidable losses range from 8 to 30%; avoidable losses from 2 to 40% (or higher). The importance of quickly achieving and maintaining oxygen-free conditions has lead to improved equipment and techniques for precision chopping, better consolidating, rapid filling and complete sealing. Delayed silo filling and inadequate sealing (ie. in bunker and clamp silos) predispose a silage to high respiration losses, surface wastes, and aerobic losses during the feedout period (Takano et al., 1983).

Present data show that DM content and silo type have the greatest effects on in-silo losses. In a series of experiments with grass or grass/legume silages, there was a marked reduction in loss with increase in DM content of the ensiled crop (Zimmer and Wilkins, 1984). When unwilted silages made with formic acid or formic/formalin were compared with wilted silages made without additives, mean in-silo losses were 16.3 and 7.9%, respectively. In a summary of 42 silages, all made in 3 X 15 m tower silos, Bolsen et al. (1984) reported in-silo losses of 17.0% for sorghum silages and 10.5% for corn silages. Presumably the differences reflected the lower DM content of the sorghums (30.1%) than for corns (37.1%) and more extensive fermentation for sorghums. Most of the in-silo loss data in the literature with different silo types were not obtained in direct comparisons and must be regarded with caution. However, in a review of 721 silages, Zimmer (1980) concluded that solid construction of silos, to minimize air-entry, in combination with harvesting crops at higher DM will reduce both in-silo losses and variation in silage quality results.

Under farm conditions, aerobic losses which occur after a silo is opened for feed-out may exceed the losses from all other sources combined. In the absence of procedures to measure these losses in the farm silo, laboratory studies indicate that daily DM losses are between 1.5 to 3.0% for each 10°C rise in the silage temperature above ambient

(Woolford, 1984). Although considerable effort has been made to find pre-ensiling treatments and practices which will prevent aerobic deterioration, control still depends on good silo management techniques. These include: 1) rapid silage removal (particularly in warm weather), 2) maintenance of a compact silage face, and 3) attention to silo design.

A recent innovation, bale silage, could make it possible for more small-scale farms to conserve forage as silage. These high density, low DM round bale packages, weighing approximately 300 to 500 kg, are either stored in individual plastic bags or stacked and covered with a plastic sheet. The limited research with bale silages indicate that variation in quality between bales can be high, prevention of aerobic spoilage due to air-entry from holes in the plastic is a problem, it is difficult to bag the bales quickly, and waste during feeding can be excessive.

NUTRITIONAL VALUE OF CONSERVED FORAGES

The nutritive value of hay and silage ultimately is determined by animal production--live weight gain, milk production, or wool yield--which is a function of voluntary intake, digestibility, and nutrient adequacy of the forage or ration. When nutritive value is combined with net harvested forage yield and net hay or silage after conservation, it is possible to measure land productivity as the amount of product marketed/ha. There have been relatively few experiments during the past decade that make possible the estimation of the overall efficiency of different conservation-feeding systems. For grasses and legumes, it is clear that early cut material gives much higher land productivity than late cut, despite a higher DM yield/ha for the more mature forage (Honig et al., 1983). They showed an advantage for wilted silage and barn-dried hay over unwilted silage which was due mainly to greater conservation efficiencies and increased forage intakes. A recent series of collaborative experiments, involving 13 research sites in Europe, compared unwilted silages made with acid (UWA) to wilted silages made without acid (WN) Zimmer and Wilkins, 1984). In general, results confirmed that differences in overall efficiencies between UWA and WN silages were small, provided a satisfactory fermentation occurred in all silages and the field wilting period was not delayed. Animal performance/ha with WN silages was 91% of that for UWA silages in trials with growing cattle and 98% in trials with lactating dairy cattle.

CONCLUSION

A well-organized, efficient forage system should include a knowledge of the nutrient requirements the livestock, harvesting the crop at its optimum stage, the necessary capacity and combination equipment, and suitable storage conditions. Applying optimum hay and silage conservation practices cannot compensate for the nutritive value lost if the crop is harvested too mature. Likewise, animal production potential of a highly nutritious crop can be compromised or lost entirely to poor conservative techniques. In addition to preserving the forage with minimum DM and energy losses, practices which reduce the amount of soluble nitrogen in silage and heat damaged protein in hay must be encouraged.

Our tasks are clear--hay-making must be made less dependent on the weather and the risks of poor silage fermentation must be minimized. Finally, successful conservation-feeding systems on farms tomorrow will likely be the result of rather small "discoveries" in new technologies and "fine-tuning" the general principles of today.

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ECONOMIC OPPORTUNITIES IN SOUTHERN FORAGE/LIVESTOCK PRODUCTION

Rob Martin[1]

Comparative advantage is an economic concept that is useful in describing activity and location of agricultural production. Although the concept of comparative advantage is more generally recognized in the field of international trade, the concept has long been used to explain regional specialization in the production of agricultural commodities. As defined by Kay, "the principle of comparative advantage states that individuals or regions will tend to specialize in the production of those commodities for which their resources give them a relative or comparative advantage."

The source of comparative advantages is differences in resource endowments and capabilities. Kay states that it is "the relative yields, costs, and profits which are the important for this principle". For that reason, comparative advantage as used in this discussion may be called relative advantage but we may for a moment at least abstract from the forces of international trade and concentrate on domestic uses of land, labor and capital which may be used for beef production and/or competing products.

If we average the American farm such that climate, soil, human and capital inputs and markets are entirely homogeneous, then farms in Alabama and Minnesota should not appreciably differ. Of course our world is not put together in such a manner. In fact parts of Minnesota, Iowa, Illinois, and neighboring states have deep productive soils, and sufficient moisture and heat to produce corn and soybeans at levels of physical efficiency not possible in Alabama and neighboring states. However, Alabama has sufficient moisture and warmth to produce high quality forages year round. Cow-calf, stocker, and even finishing phases of the beef industry have been shown to be potential means of harvesting and selling production from southern forage crops. It seems entirely possible that forage-beef-consumption systems could be designed to utilize land resources in the South to meet beef consumption demand on a fairly self sufficient basis. But, that would be a very restrictive view of comparative advantage and the competitive crop-livestock system in U.S. agriculture to meet consumer food demand.

A question that has been raised for as long as we have had concentrated feed-lot activities is, why are calves shipped out the South and beef shipped back to southern consumers? Just like the forces of comparative advantage have resulted in concentration of grains in the Midwest and cow-calf production in the South and Mountain States, comparative advantage works within the beef industry to arrange the type and location of cow-calf, stocker and feeding production enterprises. I wish to suggest in this paper that while the above question has been worthy of much of the attention it has received, a more practical and potentially useful question for the present is how can the southern producer and industry best utilize the resource and market opportunities that are offered in a market economy relatively free of institutional restrictions.

BACKGROUND AND PERSPECTIVE

Before continuing with the question of how the beef industry can best participate in the agricultural and food economy, it should be useful to establish a common background and perspective. On the basis of the title of this paper it is appropriate to look at forage as well as livestock issues. These topics were intensely treated in the 197 conference on forage-fed beef that resulted in the publication by the Southern Cooperative Series entitled "Forage-Fed Beef: Production and Marketing Alternatives in the South." Soon after that conference a

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Livestock-Forage Review Committee was formed and produced "Recommended Adjustments in Livestock-Forage Research in the Southern Region". More recently Crom has compiled a report on the "Economics of the U.S. Meat Industry" and Daugherty has repored on "U.S. Grazing Land: 1950-82". Very recently Purcell, a contributor to much of the previous literature on these subject, has looked very seriously at beef demand and suggested that the economics discipline may have failed in its responsibility to provide analysis and guidance to the beef industry.

RESEARCH TO DEFINE OPPORTUNITIES

Three research approaches will be used to illustrate attempts to better define opportunities for the southern beef industry.

1. Macro modeling of spatial, form and time dimensions of the U. S. beef industry.

2. Micro modeling of beef enterprise decisions on representative southern farm situations.

3. Micro modeling of alternative pricing methods to reduce risks in southern stocker cattle enterprises.

Macro Modeling

Macro models of the beef industry are designed to explore questions of location, product form and time of beef output. Comparative advantage is represented by means of interregional, interproduct and intertemporal competition. The guidance of the market system within the constraints of government regulation is represented by optimization models such as linear and quadratic programming. A recent improvement in optimization techniques is available in a software package called GAMS (Generalized Algebraic Modeling System) which adds the capability of improved input data and output management and computation on microcomputer or larger system as needed to handle a particular problem.

Prior to 1980, macro models of the beef industry were only beginning to include consumer demand influences in conjunction with detail production situations as endogenous variables. Today, consumer demand for beef in more than one product form as well as chicken, and pork are included. Unpublished work on such a macro model by Disney confirms industry trends that the country can do very well with a much smaller beef cow base herd than the peak in cow numbers experienced in the mid-1970s. However, more detail results indicates that the South, east of Texas and Oklahoma, would increase in relative share of a preferably smaller national herd.

When cow numbers in the country or an area of the country decline, pasture capacity is released for other uses. The most direct other use of land, labor, and management as well as specific facilities and equipment once used in cow calf production is stocker production. Other uses range from crop production to timber where transferability of inputs may be substantially impaired.

In sum, macro models of the U. S. beef industry are now telling us that we should not expect beef cow numbers to expand much above a 35 million national herd. The South is expected to account for 12 to 14 million of these cow numbers. Even so, the South has abundant pasture and cropland pasture capacity to stocker the feeders from this cow herd. Thus the weight produced in confinement feeding can be reduced, thereby reducing both the amount of feed grains required

and the amount of solid waste by-product accumulated in meeting the nations demand for high quality beef.

Micro Modeling: Beef Production

Macro outcomes in any industry with the number of participants as included in the beef industry are composites of individual decisions to reach business goals held by the numerous participants in all stages of the industry. Modeling of firm level decisions for beef producers in the South has focused on

competition among cow-calf, stocker and finishing stages of production in the use of land, labor and capital resources. Forage from grazing as well as harvested crops, grain and by-product feeds such as poultry litter have been prime factors influencing the use of land, labor and capital inputs to accomplish beef production.

A recent Alabama study (Kolajo and Martin) analyzed fifteen cattle feeding systems on a 325-acre representative farm. Feeding systems included grazing stockers on cool-season forages and feedlot finishing. Cool-season grazing began in November and continued through March, April or May. On the end of March and end of April dates cattle could be continued on grazing, placed in the feedlot, or sold. On the end of May date cattle could be placed in the feedlot or sold. Cattle placed in the feedlot were fed for periods of 30, 60, 90, or 120 days. Thus, cattle off grass could be sold at the end of March, April of May and cattle from the feedlot could be sold at various weights at the end of April through the end of September. Further, calves placed on cool-season grazing were at weights of 350, 450 and 550 pounds.

Yield and price risks were represented in an linear programming model that maximized expected returns subject to alternative levels of risk (where risk was defined as mean absolute deviations from expected returns). Results indicated an income and risk advantage for stocker programs that carried calves of varying initial weights on cool-season grazing from November through May and then to market without any feedlot activity. Feeding for 30 to 60 days while in most cases providing positive net returns, simple reduced to profit potential that could have been gained from selling off of grazing one to two months earlier. Furthermore, price risk was not reduced by choosing to lower returning feedlot options.

In sum, stocker production on cool-season grazing is very often the most profitable beef enterprise opportunity for many southern cattlemen. A reduced southern and nation beef cow herd makes room for the stockering phase as well as still supplying calves that may profitably be stockered prior to placement in the feedlot. Stockering is likely superior to finishing in the South from both a return and a risk standpoint. While cow-calf enterprises may have less risk exposure than either stockering or feedlot operations, returns from cow-calf operations are usually less than stockering.

Micro Modeling: Marketing Live Cattle

Macro and micro modeling of the beef industry yields results that prominently include stockering of beef cattle. A deterrent to producer adoption of this production alternative is the large financial outlay for feeder calves and the substantial impact that this financial amount and price variability have on income risk from stocker production. The usual level of income variability from stocker production far exceed income variability from other prominent farm enterprises including cow-calf and crop production. Therefore, stocker operators must consider more complex forms of pricing strategies than crop producers who are influenced by government price support programs. And, stocker producers experience price risk at both the purchase price and selling price levels and the selling price value is at a higher financial level per animal than for the cow-calf producer.

A recent study of alternative pricing methods of reducing price risk in stocker cattle marketing evaluated several alternatives that producers may take to reduce price risk (McKissick, Martin and Kolajo). Foward pricing of stocker cattle produced in Alabama was estimated to be an important strategy for reducing income risk while maintaining income level. Further, the introduction of feeder cattle options provides a unique risk management alternative to very sophisticated futures hedging strategies. However, current producers' use of foward pricing strategies is not indicative of the risk and income tradeoffs which have been identified in

pricing analyses. Research into why this situation exists is needed to formulate future educational programs.

CONCLUSION

This examination of economic opportunities in southern forage/livestock production has been rather targeted to one research economist's experiences over several years. Yet, it may provide for some progress in interdisciplinary cooperation in design, conduct and interpretation of research. An attempt has been made to conduct at least a windshield survey of ideas from the present back to and including the 1975 forage fed beef conference. Some fourteen years later have shed much "hind sight" on the projections that were made at that conference. Perhaps the most unseen happening has been that of poultry replacing more than 15 percent of per capita beef production. Even so, the worst thing that responsible leaders of a major industry can do is to panic and make anything other than the best next move in the competition for consumer food and meat expenditures. As Dr. Purcell suggested so well, disciplines need to be on top of major issues such as the major restructuring of meat consumption patterns to provide guidance to industry participants.

A view of the cow-calf, stocker, finishing trade off in the South seems to indicate advantage to the stocker phase. This advantage will continue to depend on many holders of land, labor and capital resources continuing to choose cow-calf operations. Also, an effective feedlot industry must continue either in present locations or points not more distant from the South than present locations.

A major component in answering the above stated question of how can the southern producer and industry best utilize resource and market opportunities, is the price risk in buying and/or selling beef animals. This problem is most significant in the case of the stocker enterprise. The largest cost factor for the stocker enterprise is the feeder calf. The market value of the product of a stocker enterprise is subject to fluctuations in grain and meat prices. Although grain prices have substantial price stabilizing influence caused by government farm programs, meat price have not been greatly affected by institutional factors other than inflation based price ceilings of the early 1970s and industry regulation. Foward pricing strategies were found to be superior to the cash market alternative currently used by most cattlemen. Efficiencies gained through pricing can be reflected back to strengthen the industry at all stages.

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IMPLICATION OF FERTILIZER INDUSTRY TRENDS ON SOUTHERN FORAGE PRODUCTION

B. C. Darst

INTRODUCTION

A brief review of the fertilizer industry in the U.S. shows a period of rapid growth beginning in the early 1950s and lasting into the late 1960s. (Indeed, the technology developed in World War II in explosives paved the way for the synthetic nitrogen (N) fertilizer industry.) At the same time, the industry continued to build new production facilities and to upgrade its delivery system. Increased production capabilities created a need for additional retail outlets to move products to the grower.

The fertilizer market place was soon crowded with newcomers, particularly energy companies, seeking a share of the sales of this vital crop production input. Competition became fierce, with retail fertilizer plants popping up on nearly every agricultural corner, particularly in the corn and soybean production areas of the Midwest. Competitive fires were fueled by rapid development, including dry bulk blending, big and fast application equipment, and the expansion of the fluid fertilizer segment which continues to increase its market share through aggressive, research based marketing programs.

During this period of rapid expansion, product lines were expanded, application techniques became more diversified and the particular needs of regional crops... including southern forages...were more closely met. Both bulk blending and the use of direct application materials, such as 0-0-60 on hybrid and common bermudagrasses, were major contributors to the meeting of specific nutritional requirements.

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The 1970s and early 1980s were a mixed bag. The fertilizer industry saw high prices, then low prices; product shortages followed by excess production. Offshore competition, particularly N imports, put extra pressure on a North American market that was seeing demand level off, even drop, while production capacity had been steadily built beginning in the mid 1960s. The industry has gone through dramatic changes in the last few years, companies being bought and sold and major consolidation taking place. Equilibrium has not yet been reached.

PROFILE OF THE FERTILIZER INDUSTRY - PRODUCTION AND CONSUMPTION CHANGES, 1960s TO THE 1980s

The fertilizer industry has been characterized by major changes in production capacity since the mid 1960s, changes involving significant increases as well as shifts in locations of production. Product use profile and distribution methods have changed as well. The following discussions on N, phosphorus (P) and potassium (K) highlight some of those changes. They deal mostly with North America, with emphasis on the U.S.

N Production, Product and Consumption Changes

North America had an annual ammonia production capacity of about 11 million tons in 1965, 90% of which was in the U.S. and 10% in Canada. There were 98 production facilities, with an average annual output of 110,000 tons. Twenty years later, capacity had more than doubled, up to about 25 million tons, declining to about 22 million tons since 1985, Table 1.

Table 1.
A comparison of North American anhydrous ammonia production capacity, 1965 vs 1985

Year	Capacity, 1000 T/Yr	Production in U.S, %	Average per plant, T/Yr
1965	11,000	90	110,000
1985	25,000	75	350,000

One of the most dramatic changes has been in construction activity and individual plant production capacity. Of the 98 producing plants in 1965, only 10 remain active today. Another 54 new plants were built in the 20-year period between 1965 and 1985. Average annual plant production capacity is 350,000 tons. Today, the U.S. accounts for approximately three-fourths of the total and Canada one-fourth of the total of North American N production. In the last 20 years Canada has become a major N supplier, primarily because of its ability to provide inexpensive natural gas, the major raw material for ammonia production...and consequently other N fertilizer sources.

Increases in production capacity have been accompanied by changes in the kinds of fertilizers produced and the system used in getting them to the grower. Back in 1965, the single largest N source came from compound NPK fertilizers manufactured at small, regional ammoniation plants. Nitrogen producers were fully integrated in the business, owning retail outlets as well as production facilities. Direct application ammonia was as important then as a N source as it is today.

Use of urea has risen six-fold since 1965 and UAN solutions have more than tripled in use, now representing about 20% of U.S. consumption. At the same time, ammonium nitrate and ammonium sulphate consumption now represent only seven percent of the total. For the most part, chemical mixtures have been replaced by blends and producer owned retail outlets have been sold to others.

In 1965, N imports and exports were nearly identical at a half-million tons each. By 1985, U.S. exports of N had jumped to nearly 3.3 million, 40% of which was in the form of ammoniated phosphates. At the same time imports had climbed to nearly 4.4 million tons with ammonia accounting for more than 60% of the total. During this time Canada switched from importer to major exporter of N to the U.S.

Stagnant, sometimes declining, North American demand coupled with rising imports and unpredictable exports forced major changes in the business in the last few years. The industry will continue to face major challenges in the future...environmental concerns, cost of natural gas, government policies on trade, farming, natural resource protection and others.

A major challenge facing the N fertilizer industry in the future will be the concern of nitrates in groundwater. Already federal and state laws are impacting N use. In Nebraska, for example, N applications can be made only at certain times on some soils and under specific management situations. In Iowa, a new tax on N fertilizers will be used, at least partially, to evaluate systems of crop production that will allow reduced use of fertilizer N.

I am confident the industry will respond in a positive manner. It is already utilizing new technology in the area of N stabilization in the soil by the use of nitrification and urease inhibitors. The adoption of other best management practices (BMPs) will result in more efficient crop use of N. (This will have a negative impact on demand.)

Phosphate Production, Product and Consumption Changes

Many of those same factors that have influenced swings in N consumption have also impacted P production and demand. Since 1965, U.S. phosphate rock production has doubled, from 30 million to a high of 60 million tons in 1980. Florida and North Carolina are the two largest suppliers, operating 19 mines today compared to 10 back in 1965.

In the mid 1960s U.S. rock exports totaled more than 8.0 million tons, of which Canada imported more than 1.1 million tons. Today the case is significantly different. A total of more than 2.0 million tons of phosphate rock will probably be imported into North America in 1989, about 1.0 million to the U.S from Morocco and another million to Canada from Togo. Still, offshore

imports into North America will account for only 4% of the amount consumed in North America this year.

Export demand for processed phosphates exploded, rising 10-fold between 1965 and 1985. Seeing this trend, coupled with domestic growth in demand, the industry moved to capitalize on a "boundless" opportunity by adding capacity (see below). Today, North American phosphate producers export more than is consumed domestically.

Twenty years ago North American phosphoric acid production capacity was about 3.0 million tons of P_2O_5; today wet acid capacity is about 12 million tons. At the same time demand rose from about 3.9 million tons in 1965 to a peak of 6.0 in 1980. Consumption fell off after 1980 and has not yet climbed back to the level enjoyed by the industry that year, Table 2.

Table 2.
A comparison of North American phosphoric acid production capacity and P_2O_5 consumption, 1965 vs 1985

Year	Phosphoric acid production, 1,000T/Yr	P_2O_5 consumption, 1,000T/Yr[1]
1965	3,000	3,900
1985	12,000	4,600

[1]Peak consumption of 6.0 million tons in 1980

Normal superphosphate and compound NPK production gave way to high analysis, ammoniated phosphate production in a span of just 15 years, beginning in the 1960s. The evolution of new, high quality super and ortho grades of phosphoric acid have developed the fluid blend and suspension segments of the market place. It has also opened up areas of increasing need for fertilizer sulphur (S), particularly in the South.

Those same forces that influence the future for N fertilization will also affect P. Although most environmental issues will focus on production, significant emphasis will also be directed to the impact at the farm level.

Potash Production, Product and Consumption Changes

In 1965, the U.S. dominated world potash (K_2O) production, supplying nearly 3.5 million tons or about one-fourth of total world K_2O production. West Germany was close behind with about 20% of production; the Soviet Union ranked third. At that time Canada was just developing its rich deposits in Saskatchewan and produced about 1.6 million tons.

Production in the U.S. has faded, but the Saskatchewan capacity grew, so North America remains a major producer. The Soviet Union is now the world's largest producer of potash, accounting for 37% of total production in 1986 compared to 23% in Canada and only 3.0% in the U.S. However, Canada has by far the world's greatest potash reserves, Table 3.

Table 3.
World potash reserves by country

Country	K_2O reserves (million tons)	Percent of world total
Canada	11,500	58
U.S.S.R.	5,500	29
East Germany	880	5
West Germany	550	3
U.S.A.	330	2
Brazil	220	1

Potash consumption in the U.S. was about 3.2 million tons in the mid-1960s, but doubled to 6.6 million in 1980. As with phosphate, demand since then has cycled and totalled about 5.5 million tons last year. North American consumption will trend upward only 1-2% for the next couple of decades. At the lower growth rate, we will barely achieve the 1980 consumption level by then.

Offshore sales of North American potash is another story. Last year, for example, Canadian producers posted a record volume, selling more than 4.0 million tons into the export market, a market that is expected to grow well into the

future. Within the next 20 years New Mexico mining will probably cease, so the U.S. will depend even more strongly on Canadian potash, but will also continue to be supplied by product from sources outside North America.

MARKETING SUPPORT SYSTEMS AND CHANGES IN THE FERTILIZER INDUSTRY

In the early years of the fertilizer industry, soil deficiencies of essential nutrients were common, so selling this vital crop production input was relatively easy. The industry was mainly a delivery service for the grower. Research and Extension programs sold the need for sound fertilizer programs.

The Land Grant University system continues to be the foundation of marketing for the fertilizer industry today. The retail dealer has also taken on a more important role and has stepped out front in representing the industry at the local level. The industry itself promotes and supports research and education programs that offer economic advantages for the grower and environmental protection for us all.

The following sections detail some of the support systems that have in the past and will continue to bring about improvements in fertilizer marketing.

Development of the Fertilizer Market - A University Base

We must look to the Land Grant University system to find the roots of the U.S. fertilizer industry's marketing programs. The universities do the research. They train the scientists who lead in agronomic research and will continue to do so.

The universities train the teachers who extend new production technology developed through research. The Cooperative Extension Service, operating across the U.S. for 75 years, takes new research findings, digests them and provides answers to production questions in forms that can be understood by fertilizer dealer and grower alike.

Those in the fertilizer industry recognize and acknowledge the essential role played by Extension...in soil fertility, plant physiology, engineering, plant breeding...in all those disciplines that form the cutting edge in production agriculture.

Changes in marketing philosophy in the fertilizer industry...continuously for the better...is a classic example of how the Land Grant University system justifies its reason for being.

Role of the Fertilizer Dealer

To fully grasp the significance of changes in the fertilizer market place in the past 40 years, one must have an appreciation for the role the retail dealer plays in the marketing of fertilizers, chemicals, seed, etc. He is central to the industry's success.

Table 4 documents the importance of the dealer in influencing the grower in his buying decisions. Information in the table was taken from an Indiana survey conducted by Purdue University and is in agreement with similar studies by Agrico Chemical Company, the Potash & Phosphate Institute (PPI) and others.

Table 4 says that production information generated through agronomic research must be largely channeled through the dealer if it is to reach the ultimate consumer, the grower. In other words, he is the number one extender of production information.

Table 4.
Growers go to their dealer for help with crop production problems

Information source	All farmers	Large farmers[1]
Seed, chemical & fertilizer dealer	55.6	75.0
County Extension Agent	24.0	8.1
Consultant	4.7	13.5
Others	15.7	3.4

[1]More than 200 acres farmed

The agricultural retail dealer has been on the front line and has survived. He has been forced to deal with high prices, low prices, product shortages...caught in the middle between suppliers and growers. He has adjusted and is still there. He continues to grow in stature, maturing from the early image of delivery service and product supplier to his current status of crop production advisor to his customers. His role is, and will continue to be, critical to the advancement of the fertilizer industry through sound agronomic marketing principles.

Fertilizer Industry Support of Research and Education

The leadership in the fertilizer industry has long recognized the importance of agronomic...and economic...soundness of marketing, based on research, reflected in its support of PPI, the Foundation for Agronomic Research (FAR), the Fluid Fertilizer Foundation (FFF), and through direct grants to universities and other agencies. The trend is toward a continuing support from the industry. The following few examples, taken from research supported by PPI and FAR, illustrate specifically how this trend impacts on southern forage production.

Table 5 summarizes the results of a three-year study supported by PPI and was designed to show how N source can influence both potential grower profits and environmental protection. (I should point out that many scientists in the fertilizer industry have been promoting fertilizer use on the basis of agronomics, economics and environmental protection for several years now.)

One of the big concerns in crop fertilization today is N use efficiency. Balanced fertility and/or fertilizer programs are one effective method to help insure best N use by the crop while minimizing the chances of N leaking into the groundwater. This Texas research was supported by FAR and illustrates how N balanced with P produces more yield while reducing soil N, Table 6.

Table 5.
Relative yields of bermudagrass with five N sources, Haskell, OK

Nitrogen source	Relative yield, %			
	1978	1979	1980	3-Yr Ave
Ammonia	86	80	96	89
Ammonia, CF[1]	80	80	83	82
UAN solutions	92	100	100	99
Urea	88	95	89	92
Ammonium sulphate	100	99	97	100

[1]Cold Flo

Table 6.
Phosphate increases yields and improves N use efficiency on irrigated wheat

Rate, lb/A		Yield,	N efficiency,	N balance
N	P_2O_5	bu/A[1]	bu/lb N	sheet[2]
0	0	22	--	--
200	0	62	0.31	+75
200	40	105	0.52	+ 5
200	80	120	0.60	-30

[1]N removal adjusted for clipped forage
[2]N applied was less than (-) or more than (+)uptake in grain

Note that 40 lb/A P_2O_5 resulted in a reduction in residual soil N of 70 lb/A while boosting yields by 43 bu/A above that for the zero P_2O_5 treatment. When the P_2O_5 rate was increased to 80 lb/A, yield response was 58 bu/A over the zero P_2O_5 treatment, and more N was removed from the soil than was applied as fertilizer.

Research results in Table 7, part of a series of projects that PPI and FAR began to support at LSU, Homer, LA in the mid 1970s...and still do, show the relationship among potash rates, yield and soil K status over a long period of time. This series has resulted in a whole new philosophy of K fertilization on high yielding

Table 7.
Influence of K_2O rates on soil K levels

Year	K_2O rate, lb/A		
	0	200	400
	--- Soil K, lb/A ---		
1	83	98	82
2	45	77	76
3	26	49	70
4	26	49	51
5	25	51	72
6	26	59	102
Sixth Year DM Yield, lb/A	6,067	11,131	11,262

warm season perennial grasses such as Coastal bermudagrass, particularly on sandy soils with low K supplying powers.

The above are but three examples of how the fertilizer industry, through its market support programs, funds research that objectively evaluates the fertilizer input. Obviously, the industry also supports education and implementation programs that complement research efforts.

SUMMARY

This paper has been a somewhat generic overview of the fertilizer industry and its impact on crop production. However, the points made are relevant to southern forage production as well. The trends in supply, demand and price have significant influence on fertilizer use in a given year or over a period of time. World markets, import/export balance and trends in consumer preference dictate decisions in the fertilizer market place as in any other industry. Those decisions in turn influence management of forage crops, both short-term and long-term.

FUTURE DIRECTIONS FOR FORAGE RESEARCH AND PRODUCTION

Don Holt

ABSTRACT

Pasture and forage researchers, extension people, producers, and other agricultural decision-makers should be encouraged to take a strategic planning approach to facing the challenges of the future. Enlightened decision-makers at high levels of agricultural organization will focus on building and maintaining research and development infrastructure and institutional capacity. They will foster decentralized management and utilize as fully as possible the creativity of the "front-line" people (teachers, researchers, extension people, farmers, suppliers, etc.) in the great conglomerate we call agriculture.

INTRODUCTION

Pasture and forage researchers, like other agricultural researchers, would like not only to know the future direction of forage production and research, but also to influence that direction in positive ways. Very complex issues are involved, however, and there is much disagreement about them. How can we analyze this situation in ways that yield useful insights and can lead to constructive action? I find it helpful to think about agricultural challenges in terms of strategic planning.

Strategic planning is a routine activity in most private firms. Don Duvick, Vice-President for Research of Pioneer Hybrids, International, lists important strategic planning questions as follows: What is our business? Who are our clients? What are the forces of change in our business? What do we have in place to cope with these forces? What should we put in place to cope with these forces?

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The process of strategic planning is a subject of study in business schools. The concept has evolved from long-range planning to strategic planning. Some think it might be more aptly described as strategic marketing. There is a body of literature on the topic.

The modern concept of strategic planning focuses on change. Economic, social, political, and, especially, technological changes are occurring more rapidly and the future is becoming less predictable. Planners need to identify the forces of change, describe a number of alternative scenarios, lay plans for dealing with them, and, in general, make their organizations more flexible, adaptable, and responsive to change.

In this document, I propose just a few responses to the strategic planning questions, as they relate to pasture and forage research. A more thorough, broadly based strategic planning effort would be very valuable to both researchers and producers of pasture and forage. The suggestions about management of research and development stem from my own experiences in working with the private sector and reading recent literature on management philosophy and practices of private firms.

THE BUSINESS OF PRODUCING PASTURE AND FORAGE

For purposes of this discussion, I request that you think of the pasture and forage industry of our nation, not as a large number of individual farms and farmers, but as a manufacturing conglomerate. This conglomerate is made up of suppliers of inputs; producers, processors, distributors, and marketers of forages, animals, and animal products; financial institutions; public and private research, development, and educational groups; and farm organizations, among other individuals and groups.

As pasture and forage researchers, we are an important component of this vast conglomerate. In many ways, we serve as its research and development arm.

Individually and collectively, we make important research, development, and educational decisions. As we portray research needs to decision-makers in various organizations, agencies, and in government, we may influence policy decisions that have far-reaching implications for the industry.

WHAT IS OUR BUSINESS?

In September of 1986, a conference on the future of Illinois agriculture was held at the University of Illinois. Participants included farmers, agribusiness people, scientists, consumers, environmentalists, and leaders of diverse agriculture-related organizations. Among other assignments, the group was asked to develop a statement of the mission of Illinois agriculture.

The mission statement included four components: 1) to increase the volume of profitable business in Illinois agriculture, 2) to conserve natural resources, 3) to maintain and improve environmental quality, and 4) to preserve rural institutions. While the conference participants agreed that all four objectives were important, they disagreed on order of priority.

How can we achieve a mission that is so obviously complex and involves such diverse constituencies? How do we set priorities in such a complex situation? How do we know where to start?

During the late 1950's, when I was a farmer in northern Illinois, the National Farmer's Organization was organizing county chapters. This organization is similar in philosophy and policy to a labor union. They proposed to have holding actions, during which participating farmers would withhold their grain and livestock from the market, with the goal of increasing prices. I disagreed with this approach for various reasons.

One day I was arguing the point with a neighbor, who was another young farmer struggling to get established. I advised him not to sign the contract binding him to holding actions, using the words, "If you sign that now, in five years they'll own your soul". His response was, "If I don't survive this year, it won't matter what happens in five years." People strive hard to survive in business, because they must meet their needs and those of their families. When the chips are down, the "bottom line" is a powerful, sometimes irresistible, force.

For this reason, I think the overriding consideration must be profitability. This conclusion may seem unduly mercenary, but I think it is simply facing the reality of competition. Those who propose changes must consider the critical issue of who must implement the changes. If farmers and agribusiness people cannot implement proposed changes as part of profitable farming enterprises, the changes will not be implemented, and nobody's objectives will be served.

WHO ARE OUR CUSTOMERS?

According to business guru Tom Peters (1988), firms that survive and thrive in the fierce competition of the global economy have certain characteristics in common. One is that they become obsessed with serving their customers. Have the pasture and forage researchers of the U. S. accurately identified their customers and tried to find out how best to serve them?

If we indeed serve as the research and development arm for pasture and forage producers, then our customers are their customers. Their customers want reliable supplies of high quality, inexpensive forages and high-quality, low-fat, safe, inexpensive animal products.

I believe that pasture and forage researchers have tended to think of the ruminant animal as the consumer of pasture and forage. We need to look beyond the animals, however, to the ultimate consumer. We should encourage the producers we serve to become much more customer-oriented.

This doesn't mean that we all must become retail market researchers, but we need to understand the unique characteristics of the markets served by forage researchers and producers. Many marketing problems can be solved and marketing opportunities created by changes in production technology and practice. The chicken and fish industries certainly have proven this concept, at the expense of producers of ruminant animals.

WHAT ARE THE FORCES OF CHANGE IN OUR INDUSTRY?

Most discussions of the rapid change in agriculture focus on the internationalization of and growing competition for commodity and credit markets. Attention is also directed to rapid technological change, including some potentials, like growth hormones, that create fear about food safety and overproduction. Changing lifestyles and food preferences and public concern about natural resource conservation and environmental quality also will have important impacts on pasture and forage research and production.

Relatively little is written about one of the most profound changes in livestock production. It has been going on for years and is driven by changing economies of scale. Illinois studies indicate that most of the economies of scale in grain production are achieved when 2,500 to 5,000 man hours of labor are devoted per year to a farm operation. This translates in Illinois to grain farms of 500 to 1000 acres. Optimum grain farm size continues to increase slowly, but because grain production is necessarily spread out over the landscape, rapid increases in optimum scale are not likely.

On the other hand, livestock feeding lends itself to concentration in space. Operations of optimum scale involve feeding millions of poultry, tens of thousands of pigs, and from 6,000 to 10,000 head of cattle. Such operations consume more grain than would be produced and require more labor than is available on a 500- to 1,000-acre farm. Thus the optimum scales of the two kinds of operations do not match.

This growing difference between the economies of scale achieved in grain farming and those in livestock feeding are pulling these activities apart. I believe we will continue to see fewer farm operations that involve both grain farming and livestock feeding. Among other implications of this change, it probably will not be feasible to return much manure to the fields that produce the grain fed to animals.

Beef cow-calf operations will probably continue to be less concentrated and to utilize considerable pasture and forage. In Illinois, more and more of these operations are quite small, involving 20 or 30 cows maintained by part-time farmers, sometimes as a hobby. If greater economies of scale and scope cannot be achieved in beef cow-calf operations, other animal products will continue to make inroads into beef markets.

WHAT DO WE HAVE IN PLACE TO COPE WITH THESE CHANGES?

Our agricultural research and development system can be visualized as a four-step process of transforming ideas into applications (Fig. 1). The steps include: 1) basic research, by which we come to understand the physics, chemistry, biology, economics, and sociology of agricultural systems; 2) developmental research, which produces specific new agricultural input and output products and practices; 3) adaptive research, whereby information is produced that enables farmers and agribusiness people to select from among alternative input products and practices the ones best suited for their specific soil, climatic, and socio-economic situations, and integrate them into effective, efficient, operational systems; and 4) technology transfer, through which the new information is transferred to users.

Much developmental research is conducted in the private sector. Adaptive research

has historically been the responsibility of the agricultural experiment stations and USDA. Technology transfer, involving both education and decision-support activities, has been the responsibility of the Cooperative Extension Service and resident instruction within land-grant institutions. The private sector plays an important role in technology transfer but cannot accomplish the entire task, because they cannot provide objective, comparative information about competing products.

The Morrill, Hatch, and Smith-Lever acts, among others, created this unique system, in which research and educational programs are conducted within the same institutional structure, usually by the same groups, and often by the same individuals. Note that these historic legislative acts were not focused on individual problems or issues.

These acts created institutional structure. They put in place an infrastructure of people, buildings, facilities, equipment, support services, and communication networks. They assured that U. S. agriculture would have the institutional capacity to address agricultural problems when and where they would arise. Through the formula funding, these acts decentralized management of the institutions, putting the decision-making close to the problems, most of which are site- and situation-specific.

By fostering the development and use of productivity-enhancing, cost-cutting, quality-improving agricultural technology, this unique research and development system propelled American agriculture into world preeminence and kept it there for a century. In recent years, however, critics of the system have raised serious concerns about its effectiveness and efficiency. Some of the concerns are reflected in various actions taken and proposals introduced in the federal government.

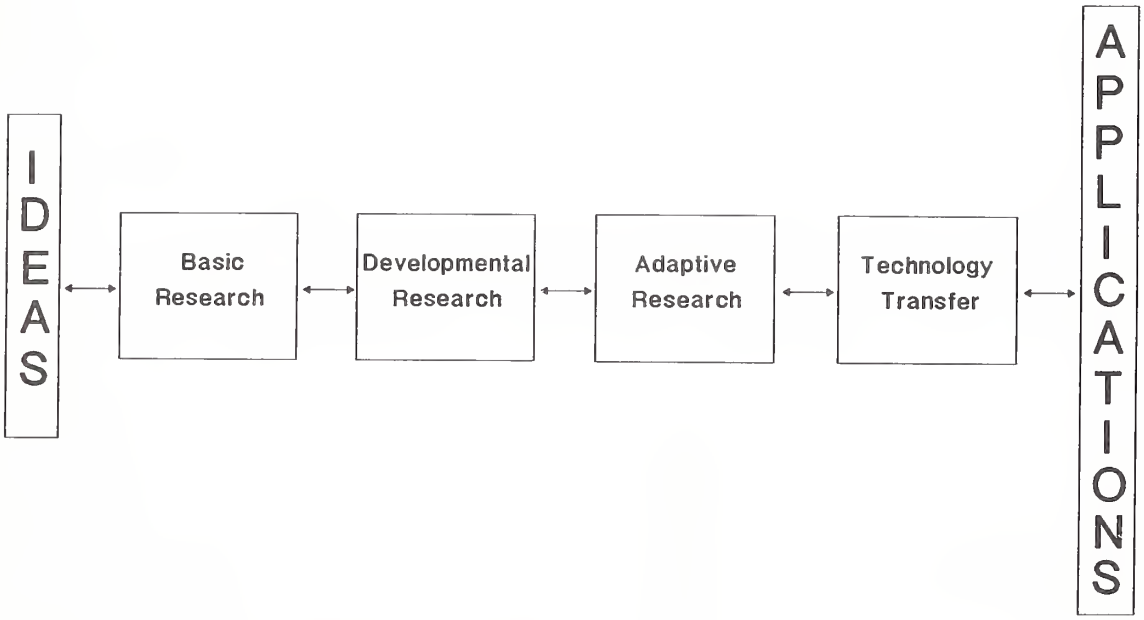

Figure 1. Conceptual model of the U. S. agricultural research and development system, depicting a linear, stepwise process of translating ideas into agricultural applications.

WHAT SHOULD WE PUT IN PLACE TO DEAL WITH THE FORCES OF CHANGE IN OUR BUSINESS?

In the last five years, the formula funds, long a major source of support for applied, production-oriented research and extension, have been cut significantly. Some saw these as the underlying cause of chronic overproduction in the industry. Some critics of formula funds complain that they allow too much management discretion on the part of university scientists and administrators.

Senator Fowler of Georgia has introduced a bill that would require the land-grant universities to embrace the low-input, sustainable agriculture approach, and would subsidize farmers who use low-input systems, to make up for income they might forego. Several bills would redirect research resources away from production research and toward developing new products and new uses for agricultural products. The so-called National Agricultural Research Initiative would greatly increase competitive grants available for basic agricultural research, and would open them to all public-sector scientists.

Each of these actions, criticisms, and proposals represents a different strategy for managing the publicly-supported agricultural research and development effort. Each would take the system in a significantly different direction. An important question, from a strategic planning standpoint is, What objectives are being served by these strategies? I hope that in the course of developing the 1990 farm bill, our legislators and other decision-makers will rethink the agricultural research and development system in the context of strategic planning.

As our nation is integrated into the global economy and agricultural markets become more international, U. S. agriculture, including its pasture and forage components, will face growing competition from other similar entities around the world. In that situation, trade policy becomes the marketing strategy of the conglomerate and domestic agricultural policy is its operational management strategy.

Research and development strategy will be especially important. The U. S. will have to pit its human capital, technology, biophysical capital, and institutional structure against the best the world has to offer. While each of these resources is important and should be assessed, I will confine my remarks to institutional structure.

Another characteristic of firms that survive and thrive in highly competitive industries is their ability to shorten product development time. How can public research and development groups shorten the time required to translate ideas into applications? As I pondered this question, it occurred to me that if we could "wire" (organize) the linear, stepwise process depicted in Fig. 1 as a parallel process (Fig. 2), development time might be shortened.

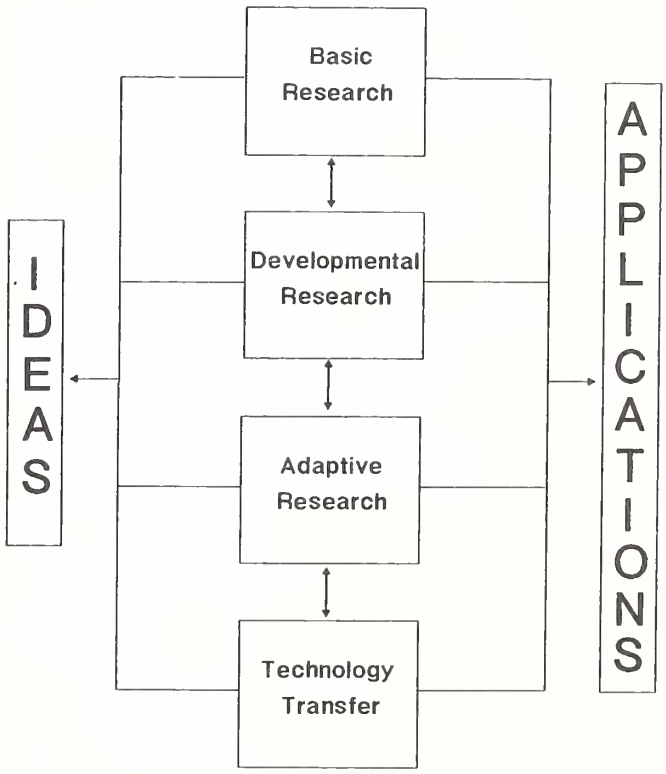

Figure 2. A parallel model of agricultural research and development, as it might be organized to speed the development of new agricultural technology.

The proposed change would require an evolutionary, not a revolutionary, change in management of land-grant institutions. Because people engaged in the essential activities--basic research, developmental research, adaptive research, and technology transfer--are usually mixed together in the same administrative units in land-grant institutions, the parallel approach is facilitated. This has been one of the great strengths of these institutions.

Recent trends toward greater specialization, more top-down management, and funding of research through federally-administered, discipline-oriented, competitive grants has tended to negate the natural advantages of the typical land-grant institutional structure and move the system more toward the linear model of operation. The linear system is driven by disciplinary concerns and disciplinary decision-making, because basic research, the starting point in the linear model, is organized along disciplinary lines.

The parallel system, on the other hand, is driven by applications goals. Typically, an initiative launched in the parallel system would have as its objective the accomplishment of a specific market goal, conservation goal, environmental goal, etc. The investigators would be organized as a self-managed, cross-functional team or task force with expertise in all aspects of achieving the goal. Administrators would be facilitators, marshalling resources to support the project and keeping the bureaucracy out of the way.

There would be basic, developmental, and adaptive researchers and technology-transfer people on the team. The team would identify specific needs for each of these activities during the planning process, thus making it possible to anticipate problems in implementation of new technology that can be addressed in earlier stages of research and development. Private sector experience suggests that over 90 percent of initiatives fail in the implementation stage, so consideration needs to be given to implementation very early in a strategic-planning process.

It often will be important to involve suppliers, producers, and consumers in the planning and execution of a project. The results would be evaluated on the degree of success in achieving the specific goal rather than the number of publications or other intellectual products generated by the research and development effort.

If the parallel system is to function successfully, sound modern concepts of institutional management will need to be employed. One of our big problems is that, at the federal level, decision-making has become very issue- and problem-oriented. Little attention is being given to maintaining and improving the infrastructure and assuring that we have the institutional capacity to carry out all the important steps in agricultural research and development.

"Corporate" level managers (legislators and agency heads) in our great conglomerate are trying to micromanage research, development, and production activities. The tremendous emphasis on basic research, thought to lead to dramatic innovation, is overshadowing the need for steady, incremental improvements in productivity. Peter Drucker, father of the science of business management, describes the overemphasis on dramatic innovation as trying to have a "mountaintop without a mountain" or a "cutting edge without a knife."

Our top public decision-makers operate through consensus, which when applied to operations, has a detrimental averaging effect. They are imposing strategies instead of establishing overall objectives and goals. They are focused on process rather than results.

For example, many influential people are pushing the strategies of diversification and vertical integration as the answer to U. S. agricultural problems. This is especially relevant to pasture and forage research, because adding animal enterprises to grain farms is widely touted as the way to save small farms,

lower inputs, conserve natural resources, and preserve the environment. Adding animal enterprises to grain farms is seen as both a diversification and a vertical integration strategy.

Proponents of this approach should be aware that diversification and vertical integration are not consistently effective survival strategies for private firms. To illustrate, some years ago White Motor Co., then a major manufacturer of heavy-duty trucks, decided to manufacture its own engines, axles, frames, and cabs, which previously it had purchased from suppliers.

By this move toward vertical integration, White put itself in competition with its former suppliers, most of whom supplied those components to several customers and so operated on a larger scale than White. White set up relatively small, inefficient manufacturing operations to supply itself and actually ended up in a poorer cost position. Ford Motor Co., the strongest competitor at that time, out-sourced virtually everything, only assembling the final product. The result was that White lost a major share of its market to Ford.

The strategy of diversification has similar problems. Any new enterprise added to diversify a farm operation or integrate it vertically must achieve enough economies of scale to be competitive. If a livestock operation is added to a grain farm as a means of diversifying and vertically integrating the farm business, the livestock operation must be large enough and efficient enough to be competitive. For reasons described before, this strategy is becoming less and less viable for the small farmer.

To deal with this situation, twelve farmers in Northern Illinois went together to build a confinement cattle-feeding operation handling over 6,000 head of feeder cattle per year. This has been very successful and has been expanded once. By cooperating, these farmers gained the necessary economies of scale in their livestock operation. If each had developed a separate 500-head-per-year feeding operation, these individual operations might have been too small to compete effectively in the market for fed cattle. In this particular arrangement, one of the farmers became the manager of the operation and the others are stockholders. This sort of organization begins to resemble corporate farming, which is distasteful to many people.

It is not unprecedented for family farmers to enter into cooperative relationships. Between 1900 and 1930, threshing rings were common. From 20 to 25 farmers might own a threshing machine and conduct their grain harvest cooperatively. In this manner they gained economies of scale necessary to allow each to utilize a large and expensive harvesting machine. Custom operations, in which farmers hire neighbors to till fields, harvest crops, etc., in trade for labor, money, or other considerations, permit them, collectively, to gain the necessary economies of scale. Innovative approaches to achieving economies of scale will be even more important as agricultural competition increases.

Much could be said about other research and development and business strategies as they are being employed in agriculture. Commodity groups are particularly enamored of the product differentiation strategy. This is an important and promising approach, but it is risky and requires very large investments in R&D. Not enough attention is given to the strategy of being the low-cost producer, which is the only viable strategy for most commodity producers (Holt, 1987).

CONCLUSIONS

You will note that in this paper I have not listed specific research topics that need to be addressed. That is because you, the individual researchers and extension people, are in the best position to make those judgments, as long as you do so with appropriate concern for the business environment in which your clients must operate and the markets they

must serve. Whether a particular research topic is appropriate depends very much on the specific situations in which the results are to be applied. Such questions cannot be adequately addressed at high levels of management and administration.

Enlightened decision-makers at high levels of agricultural organization will focus on building and maintaining research and development infrastructure and institutional capacity. They will foster decentralized management approaches that utilize as fully as possible the knowledge, experience, and creativity of the "front-line" people (teachers, researchers, extension people, farmers, suppliers, etc.) in the great conglomerate we call agriculture.

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FORAGE BREEDERS INFORMATION EXCHANGE GROUP

PHENOLICS IN FORAGE CELL WALLS: TYPES, LOCATION, AND INHIBITION TO DIGESTIBILITY

D. E. Akin

INTRODUCTION

Many factors within forage cell walls have been proposed as limitations to digestibility. Several of the more prominent ones include: cellulose crystallinity, branching of hemicellulose, and acetyl content. However, the factor most often and consistently identified as limiting plant wall digestion is the presence of phenolic compounds (Kerley et al. 1988, Brice and Morrison 1982, Morris and Bacon 1977, Waldo et al. 1972).

Phenolic compounds that are covalently bound to polysaccharides within plant cell walls have been called (1) highly polymized, "core" lignin and (2) monomeric, "non-core" lignin (Jung 1989). Recent information clearly shows that low molecular weight phenolic compounds, the "non-core" lignin, exist in cell walls that do not stain histochemically for lignin. Lignin is well established as an inhibitor to forage digestibility (Waldo et al. 1972), but the site and type of phenolics within forages, which vary with different tissues, may have particular significance in limiting quality (Akin 1982, Buxton and Russell 1988, Moore and Mott 1973).

TYPES OF PHENOLICS WITHIN FORAGE CELL WALLS

Lignins have been classified into types according to the prevalence of various groups within the polymer: syringyl (dimethoxylation), coniferyl or guaiacyl (monomethoxylation), or p-coumaryl (no methoxylation) (Sarkanen and Ludwig 1971). Oxidation of lignin (i.e., nitrobenzene) results in a distribution of aldehydes (e.g., vanillin and syringaldehyde), ketones, and carboxylic acids that help define and differentiate lignins in various plants.

Grasses have phenolic acids that are esterified within plant cell walls and that are extractable with alkali (Hartley 1983, Vance et al. 1980). The predominant acids are trans-p-coumaric (PCA) and trans-ferulic (FA), with substantially lesser amounts of benzoic, vanillic, and syringic acids (Cherney et al. 1989, Hartley and Ford 1989, Jung and Fahay 1983). Variations among plants occur in the amounts and ratios of PCA and FA (Akin 1986, Cherney et al. 1989), and information along these lines is shown in Table 1. In addition to phenolic acids, phenolic aldehydes also occur to a lesser extent in plant cell walls (Cherney et al. 1989, Hartley and Ford 1989). Forage legumes, such as alfalfa, yield substantially less of these phenolic monomers than grasses after alkali treatment (Buxton and Russell 1988, Cherney et al. 1989, Hartley 1983).

Research indicates that PCA is associated more with the lignin fraction, while ferulic acid is associated with the carbohydrate component of plant fiber (Buxton and Russell 1988, Jung 1989). Indeed, PCA is more closely associated with the fibrous residue after digestion (Harris et al. 1980) and more negatively correlated with digestibility (Burrit et al. 1984) than is FA. Research has shown that both PCA and FA are ester linked to carbohydrates in plant walls. In reviewing the literature, Hartley and Ford (1989) reported that 17% of the p-coumaric acid and 50% of the ferulic acid was recovered in fractions where the phenolic acid was linked to arabinose-xylose-xylan.

Dimers of phenolic acids in plant cell walls that are released by alkali treatment occur in plant walls (Hartley and Ford 1989). Dimers can occur with various combinations of p-coumaric acid and FA (i.e., PCA-PCA, FA-FA, PCA-FA). The total amount of these dimers range from 0.5 to 4.4 mg g^{-1} cell walls,

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values which are substantially less than the amount of phenolic acids. Hartley and Ford (1989) suggested that phenolic acids bound to carbohydrate chains could form dimers, thus cross-linking polysaccharides in the cell wall and reducing biodegradability.

LOCATION OF PHENOLICS WITHIN PLANT CELL WALLS

Histochemical stains have been used to identify sites of phenolic compounds in cell walls. Acid phloroglucinol and chlorine-sodium sulfite are two staining procedures that have been used widely to identify lignin sites and to differentiate lignin types (Akin 1982, Stafford 1962, Vance et al. 1980). Plant tissues giving a positive reaction with these stains are the most resistant to digestion and comprise a high proportion of the nondegradable residue (Table 2).

Acid phloroglucinol (Wiesner test) indicates aldehyde groups (Clifford 1974), and the deep purplish color has been reported to indicate coniferaldehyde groups in plant walls (Sarkanen and Ludwig 1971). Tissues giving positive reactions with acid phloroglucinol are the most resistant to degradation by rumen microorganisms, and usually show negligible loss of plant walls using microscopic methods (Akin 1982). Further, such tissues (e.g., xylem and

Table 1.
Alkali soluble phenolic acids from grasses

Grass	Phenolic acids (mg/g dry wt) p-Coumaric	Ferulic	Reference
Warm-season			
Coastal bermudagrass	6.9	5.8	Data supplied by M.E. Snook[1]
Coastcross-1 bermudagrass	6.7	4.4	Data supplied by M.E. Snook[1]
Zea mays[2]	4.3	2.3	Hartley and Jones (1978)
Digitgrass	5.3	3.0	Jung and Fahey (1983)
Bahiagrass	5.8	3.8	Jung and Fahey (1983)
Sorghum	4.2	4.2	Data supplied by M.E. Snook[1]
Cool-season			
Kentucky-31 tall fescue	3.4	2.8	Data supplied by M.E. Snook[1]
Boone orchardgrass	1.9	4.0	Data supplied by M.E. Snook[1]
Italian ryegrass[2]	1.5	6.4	Hartley (1983)
Reed canarygrass	.8	2.1	Burritt et al. (1984)
Smooth bromegrass	1.3	2.5	Burritt et al. (1984)

[1]USDA, Athens.
[2]Mg/g plant cell wall.

Source: Akin, 1986.

Table 2.
Histological reactions and digestibility of selected grass tissue

Acid phloroglucinol		Chlorine-sulfite	
Xylem, blade and stem	(U)[1]	Sclerenchyma, blade	(P)[1]
Sclerenchyma ring, stems	(U)	Parenchyma bundle sheath, warm-season, blade	(P)
Parenchyma, particular grasses, mature stem	(U)	Parenchyma, particular grasses, mature stem	(P)

[1]U=undigested, P=partially digested.

Source: Akin (1982, 1986, 1989)

mestome sheath) are resistant to extractive chemical treatment to a greater extent than other tissues (Barton and Akin 1977, Spencer et al. 1980), and have phenolic compounds less readily oxidized by permanganate (Akin et al. 1985). Acid phloroglucinol appears to consistently demonstrate the most resistant tissues to degradation in forages.

The chlorine-sulfite positive tissues (Table 2) are less refractory to biodegradation but still are poorly digested. Tissues giving a positive reaction (e.g., leaf sclerenchyma) are often modified extensively by chemical treatment such as alkali, resulting in modified cell walls that are totally degraded (Spencer and Akin 1980). Further, stem parenchyma, which is chlorine-sulfite positive in mature internodes, was totally delignified with permanganate oxidation and was subsequently degraded totally by rumen microorganisms (Akin et al. 1985). Chlorine-sulfite also stains rigid walls of living tissues (e.g., parenchyma bundle sheath), particularly in plants grown in stressful environments (Akin 1986).

Other compounds (e.g., safranin and azure B) have been listed as potential stains for lignin, but their reactions are not specific. Diazonium salts have been used as a stain for plant wall phenolics (Harris et al. 1982), but their use has not been extensive. While the mechanisms for other stains are not known (Sarkanen and Ludwig 1971), the reactions for diazonium salts are well documented for phenolic compounds (Morrison and Boyd, 1966). Research using diazotised sulfanilic acid has shown a positive reaction in chlorine-sulfite positive, but usually not in acid phloroglucinol positive, tissues (Akin, unpublished 1988), and the diazonium salt reaction is consistent and stable. A variety of diazonium salts is available for use, but their application has not been widespread.

METHODS OF INHIBITION

The rumen microbial population is a complex mixture of anaerobic bacteria, protozoa, and fungi that produces an abundance of enzymes against all plant polysaccharides (Akin 1986, Hungate 1966). It is hardly conceivable that glycosidic bonds or branch chains of hemicelluloses could do more than briefly slow the rate of plant degradation by the myriad rumen microbes and their enzymes. Phenolic-carbohydrate complexes released into the medium after incubation with "cellulase" or present in the rumen (Gaillard and Richards 1975, Hartley et al. 1974) indicated that the phenolic compounds limit utilization of an otherwise digestible substrate. In more direct studies, artificial lignification using peroxidase, peroxide, and eugenol of degradable cellulose reduced digestibility by fungal cellulases by about 50 percentage units (Gressel et al. 1983). Further, esterification of FA and PCA to forage fiber also decreased digestibility (Sawai et al. 1983), further establishing that covalently linked phenolic acids lower fiber degradability.

Research has indicated that PCA particularly plays an antiquality role in forages. Correlative studies have shown a higher negative relationship for digestibility with PCA as compared with FA (Burritt et al. 1984, Chaves et al. 1982). p-Coumaric acid also has been shown to be associated with the least digestible portion of forage (Harris et al. 1980) and to increase with age in some grasses (Buxton and Russell 1988). Jung (1989) pointed out that the correlative relationship of PCA with digestibility may be influenced by "core" lignin, since PCA is associated with lignin while FA is not.

It seems clear that covalently-bound, polymerized and monomer phenolic compounds reduce utilization of fiber and pose a major limitation to quality. Less clear is the role of phenolic compounds as toxins to rumen microorganisms. Such compounds are notorious for damaging microbial membranes and inactivating enzymes (Joklin et al. 1980). It seems plausible to suspect that plant phenolics in fiber are toxic to rumen microbes. However, polymerized phenolic compounds (i.e., lignin) were not toxic to rumen

microbes (Han et al. 1975, Kamstra et al. 1958). Further, dimers of PCA were also found to be essentially non-toxic to mixed rumen populations and to rumen fungi (Hartley and Akin 1989).

Phenolic monomers identified as plant wall components have been shown in several in vitro studies to inhibit growth and activity of rumen bacteria, protozoa, and fungi (Akin, 1986). Effects of particular compounds are shown in Table 3. In addition to the inhibition of intact microbes, PCA, FA, and vanillin have also been shown to inhibit fiber-degrading enzymes free from rumen bacteria (Martin and Akin 1988). In vitro studies also have indicated that phenolic monomers reduce the potential for bacterial adhesion to substrates, particularly for Bacteroides-like organisms (Akin et al. 1988, Varel and Jung 1986). Despite the toxic nature of phenolic monomers in vitro, toxic inhibition of rumen microorganisms in vivo may not occur or be a major factor because of: (1) a relatively low concentration in the rumen (Borneman et al. 1986, Jung 1989), (2) metabolism of monomers in the rumen (Chesson et al. 1983, Martin 1982), and (3) the complex of phenolics to carbohydrate (Hartley and Ford 1989). Indeed, additions of 2% PCA to a warm-season grass feed had little effect on digestibility parameters, with results suggesting that intraruminal metabolism modified the potential toxin (Lowry and Sumpter, personal communcation 1988). The argument for or against toxicity is further complicated, however, by the fact that certain plants such as Sorghum bicolor release high concentrations of mixed free phenolic acids under stress or physical disruption (Woodhead and Cooper-Driver 1979). Additionally, certain treatments that disrupt plant wall organization to improve biodegradability, such as alkali, release high concentrations of phenolic monomers, particularly from stems of warm- season grasses (Hartley 1983, Hartley and Ford 1989). Research indicated that inhibition to digestion of ozone-treated forage was removed once the residue was washed (Narasimhalu et al. 1989), suggesting that phenolic compounds (e.g., aldehydes) occurred as a result of ozonation and acted as inhibitors to rumen microbial digestion.

PLANT BREEDING TO IMPROVE FORAGE DIGESTIBILITY

The obvious conclusion from the work presented in terms of breeding to improve forage biodegradability is to reduce lignin concentration. How this idea is to be specifically applied is less obvious. It has been stated often that lignin composition, rather than amount, may be the more important factor. Further, the threshold concentration of phenolics within a tissue that influences digesti-

Table 3.
Influence of phenolic compounds on in vitro digestibility

Phenolic compound	% Reduction compared to digestion without phenolics: Mixed rumen microorganisms[1]	Consecutive batch culture[2]	Mixed rumen fungi[3]
Syringaldehyde	40	---	50
trans-Ferulic acid	17	10	70
Vanillin	42	---	75
trans-p-Coumaric acid	19	26	78
p-Hydroxybenzaldehyde	27	---	72
Maize cell wall extract	---	16	---
Barley cell wall extract	---	6	---

[1]Compounds at 10 mM concentrations; Solka floc as substrate (Borneman et al. 1986).
[2]Compounds at .15% (about 6 to 10 mM) concentrations; ryegrass hay as substrate (Theodorou et al. 1987).
[3]Compounds at 10 mM concentration; bermudagrass leaf blades as substrates (Akin and Rigsby 1987).

bility is also important and should be considered.

Plant breeding has resulted in anatomical alterations that reduce the barriers to digestion in stems. Schank et al. (1973) reported variations in the vascular bundles in Hemarthria stems while Schertz and Rosenow (1977) found variations in the epidermis, sclerenchyma ring, and vascular bundles in diverse lines of sorghum. Such tissues usually are acid phloroglucinol positive and are the most resistant to degradation (Akin 1986).

Another factor to be evaluated for improving degradation in grass stems is the lignification within the parenchyma. Work has shown that cell walls in this tissue become lignified with age, with the lower internodes having greater lignification (Akin et al. 1977, Akin et a. 1984). Plant breeding to delay lignification in this tissue, which is about 60% of the cross-sectioned area (Akin 1986), appears to be an area worth pursuing.

Leaf blades of warm-season grasses have an anatomy that reduces digestibility (Akin 1982). Because of the relationship of anatomy to photosynthesis in C_4 plants, modifications through breeding may affect the yield and, therefore, may not be an option for improving digestibility (Wilson and Minson 1980). Further, research in which leaf anatomy was modified in an attempt to improve digestibility in Panicum species indicated that intrinsic factors within cell walls overrode the influence of anatomy (Bohn et al. 1988). Variations in the ease of digestibility of similar cell wall types among cultivars of plants has indicated significant modifications in the composition or binding of cell walls without alterations in anatomy (Akin 1982, Hanna et al. 1976). An example of this phenomenon is the parenchyma bundle sheaths of Coastal and the more digestible Coastcross-1 bermudagrass. Recent research indicated that the concentration of phenolics within these cell walls was less in Coastcross-1, which related to a greater degradation by rumen bacteria (Akin et al. 1989, unpublished).

Brown midrib (bmr) mutations, which result in lower lignin concentrations and higher digestibilities compared with normal counterparts, occur in maize, sorghum, and pearl millet (Cherney et al. 1988, Hanna et al. 1981, Porter et al. 1978). Lignin content is significantly reduced in the bmr mutants, and the chemistry of the phenolics is also modified, resulting in variations in phenolic acids and aldehydes, methoxyl content, number of sites for esterification of p-hydroxycinnamic acids, and reduced levels of etherated syringyl units (Akin et al. 1986b, Kuc' and Nelson 1964, Kuc' et al. 1968).

Consistent effects of the bmr mutation for all species is the significant reduction in both lignin and PCA solubilized with alkali. An example of such changes in sorghum is shown in Table 4. Structural studies comparing the digestion of normal and bmr sorghum tissues indicated that the marginally or slowly degraded sclerenchyma and bundle sheath cells in leaf blades were more readily degraded in bmr plants (Akin et al. 1986a). In contrast, the highly lignified tissues (i.e., xylem and mestome sheath) were not degraded in either plant type, apparently suggesting that the threshold level of lignin as it affects digestibility had not been reduced in these tissues. Anatomical differences did not occur between these plant types.

These microscopic and chemical studies on bmr and normal plants suggest that genetic modification of cell wall phenolics occurs in non-lignifed (i.e., no histological reaction) tissues, and it is these changes that are more noticeable in comparisons of specific tissue degradation. The role of PCA seems to be of particular importance, but to date information is not available to indicate a direct influence of PCA in the specific walls.

Table 4.
Comparison of normal and brown midrib sorghum leaf blades

Plant	% Tissue types			% Fiber Components[1]			Alkali-soluble phenolic acids[1]		IVDMD[2]
	Vascular bundle	Sclerenchyma	Mesophyll	NDF[2]	ADF	PML[2]	PCA	FA	
Normal	25.3	3.9	50.5	57.5	28.3	3.7	0.36	0.57	69.7
Brown midrib	25.1	3.9	49.0	55.4	26.6	2.1	0.19	0.44	74.6

[1]NDF = neutral detergent fiber, ADF = acid detergent fiber, PML = permanganate lignin, PCA = p-coumaric acid, FA = ferulic acid.
[2]Differ at $P \leq 0.05$, other comparisons not different.

Source: Akin et al. (1986a, b).

CONCLUSION

Anatomical barriers to degradation have been reduced in stems, while the biodegradability of plant walls in leaf blades has been increased without changes in anatomy. The site or type of lignin is important to quality and at times may become a more dominant factor than total amount. Techniques are needed to assess these aspects of lignification within cell types in order to identify specific, modifiable phenolics within forages.

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ANALYTICAL PROCEDURES FOR MEASURING FORAGE TANNINS: THEIR USEFULNESS IN PLANT BREEDING

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INTRODUCTION

Tannins are polyphenolic molecules which are capable of forming complexes with proteins and carbohydrates. They range in molecular weight between 500 and 28,000, and consequently have different affinities for other organic molecules dependent upon: 1) The molecular weight of the tannin, 2) the molecular weight of the organic molecule, 3) polarity of the tannin and/or the organic molecule, 4) conformation of the tannin and/or organic molecule, and 5) the matrix in which they coexist. Inasmuch as tannins will form complexes with proteins and complex carbohydrates, they can affect forage intake and nutrient metabolism. An accurate analysis of tannins in herbage is essential to characterize its effects on animal performance and to predict forage quality.

Sericea lespedeza (Lespedeza cuneata [Dum-Cours] G. Don) is a warm season pasture legume utilized in forage systems in the southeastern USA. Lespedeza performs well under soil and climactic conditions where other pasture legumes would fail. However, it has been considered a poor quality forage because of high tannin concentration in its leaves. An ongoing breeding program exists at Auburn University to develop low-tannin lespedeza cultivars, however much of the evaluation of breeding stock has been with a subjective scoring of a leaf squashes on ferric ammonium citrate-impregnated filter paper (Burns, 1963). This procedure, though rapid, provided little quantitative information on tannin content, and therefore verification of progress of the breeding effort was difficult.

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The method commonly used to assay tannin content in sericea lespedeza is a procedure described by Burns (1963) which is based upon a methanol extraction of oven-dried samples. Other procedures have been developed using aqueous acetone extractions of fresh herbage (Jones et al., 1976). Tannins from both procedures can be analyzed by reaction with acid-vanillin. This reaction is specific for a narrow range of flavanols, including condensed tannins. These procedures can be utilized as reference methods for calibrations using near infrared reflectance spectroscopy (NIRS). NIRS offers new avenues for rapid analysis of tannins in large sample populations typical of breeding programs.

The information presented in this paper represents our efforts to develop an improved method for determining tannins in sericea lespedeza. Because tannins differ in composition and molecular weight among forages, these procedures may not be applicable for all tannin-containing species but may be used as a template for development of improved methods of analysis for individual species.

METHODS OF ANALYSIS

Extraction Solvents

A major criterion which has to be established prior to routine analysis of samples is to select the appropriate solvent for extraction. A review of the literature shows that numerous solvents have been used to extract tannins from plant materials. Not only is the literature confusing because of the number of solvents used, but different solvents have been used to extract similar plant tissue types. For example, when analyzing herbage samples the literature suggests that water (Burns, 1963; Bell et al., 1965; Markham, 1975), methanol (Burns, 1963; 1971; Markham, 1975), aqueous methanol (Markham, 1975; Foo and Porter, 1980), acetone (Markham, 1975), aqueous acetone (Markham, 1975; Jones et al., 1976; Broadhurst and Jones, 1978), benzene, chlorofrom, ether, and ethyl acetate (Markham, 1975) are suitable solvents for extracting tannins. The

solvent which should be used is dependent upon the type of tannin you wish to extract from the plant material. In forages, tannins have been extracted with water, methanol, aqueous methanol, acetone, and aqueous acetone. Therefore, one of our first objectives was to determine which of these solvents best extracted tannins from lespedeza.

Terrill et al. (1989) compared pure acetone and methanol with 70% aqueous acetone and methanol solvents for extraction of tannins in lespedeza. They found that pure acetone or methanol extracted little or no tannins from fresh-frozen or sun-cured herbage (Table 1).

Table 1. Extraction of tannins in 'Interstate-76' and 'AU-Donnelly' lespedeza with different solvents.†

	Solvent‡			
	Acetone		Water	
Cultivar	7:3	1:0	7:3	1:0
	--------- A_{495}§ -------			
I-76	0.56	0.00	0.32	0.00
AU-Don.	0.28	0.00	0.21	0.00

† Adapted from Terrill et al. (1989a)
‡ Extracts were from fresh-frozen herbage.
§ Spectrophotometric absorbance peak.

The aqueous forms of both solvents extracted tannins from the herbage but aqueous acetone gave more complete extraction than aqueous methanol. In a similar study, Petersen et al. (1989, unpublished data) compared aqueous acetone, methanol, and water for extraction of tannins from lespedeza leaves. When analyzed with the acid-vanillin procedure, 70% acetone was apparently extracted more tannins than water or methanol. This was confirmed when the extracts were freeze dried, resuspended in methanol, and tested for their ability to precipitate hemoglobin as described by Schultz et al. (1981). These studies are consistent with the findings of Jones et al. (1976) who determined that aqueous acetone is superior to methanol when extracting proanthocyanidins from legumes. Consequently, the widely used procedure for tannin analysis of lespedeza, which utilizes methanol for the extraction solvent, appears to provide erroneous and possibly misleading information.

Sample Preparation

Sample preparation appears to be another critical step in the analysis of tannins in forages. Chopping or macerating fresh plant material or wilting in the field reduces tannin content in lespedeza (Lyford et al., 1967). Goldstein and Swain (1963) found that oxidative changes may occur in forage samples when oven-dried and may be temperature dependent. Tannins are also affected by sunlight (Broadhurst and Jones, 1978).

Using 70% acetone as the extraction solvent, Terrill et al. (1989) studied the effects of preparing samples by freeze-drying, grinding fresh-frozen tisues with dry ice, sun-curing, and oven drying on analysis of high- and low-tannin containing lespedeza cultivars. They found freeze-drying to be a superior method of sample preparation (Table 2).

Table 2. Tannin concentration in 'Interstate-76' and 'AU-Donnelly' lespedeza herbage preserved with different methods.†

	Preservation method‡			
Cultivar	FD	FF	SC	OD
	--- Catechin equiv. ---			
I-76	214a§	117b	118b	101c
AU-Don.	107a	62b	49c	50c

† Adapted from Terrill et al. (1989a)
‡ FD=freeze-dried, FF=fresh-frozen, SC=sun-cured, and OD=oven-dried.
§ Means followed by different subscripts were significantly different ($P< 0.05$).

Fresh-frozen and sun-cured preparation was similar in high tannin lespedeza but fresh-frozen gave higher tannin values in low-tannin lespedeza. Oven-drying gave lowest values for both cultivars. They attributed poor tannin extraction of the fresh-frozen samples to cellular disruption during grinding and subsequent complexing of tannins with proteins and other cellular constituents during tissue thawing. Petersen et al. (1989, unpublished data) homogenized intact

fresh-frozen, freeze-dried, and oven dried lespedeza leaves in 70% acetone. Extracts of fresh-frozen leaves were higher in tannins than other treatments when analyzed by acid-vanillin and confirmed by hemoglobin precipitation (Table 3). This

Table 3. Acid-vanillin and hemoglobin precipitation from lespedeza leaves when preserved with different methods.

Drying treatment†	Acid-vanillin	Hemoglobin precip.
	-- CE‡--	-- TE --
FF	208	134
FD	132	99
OD	90	86
LSD (0.05)	19	5

† FF,FD,OD - See table 2.
‡ CE=catechin equivalents, TE=tannin eqivalents.

demonstrates that the widely accepted method of extracting oven-dried samples with methanol may not be suitable for estimation of tannins in lespedeza.

Protein Precipitation Methods

Several protein precipitation techniques are available to measure tannins in herbage. The original concept was developed by leather chemists to determine usefulness of tannins from different sources for industrial purposes (Bate-Smith, 1973). Bate-Smith (1973) developed a quantitative technique for tannin analysis using hemolyzed fresh blood. This technique has several advantages in that it tests astringency of the tannin, and being a chromogen, hemoglobin can be assayed directly on a spectrophotometer. The disadvantages of this technique are that there is a narrow range between tannin concentrations required to initiate the precipitation and that for complete precipitation (Bate-Smith, 1973); non-tannin compounds in crude plant extracts interfere with the precipitation reaction (Hagerman and Butler, 1978); a fresh source of blood is needed for the procedure; and protein precipitation by tannins is dependent upon sizes and conformations of the tannin and protein polymers (Hagerman and Butler, 1981). Consequently, the hemoglobin precipitation method may require extensive dilutions to adjust tannin concentrations within the functional range of the test, extensive sample preparation may be required to remove non-tannin components from the crude extracts, and because tannins in different plant species vary in molecular weight, hemoglobin may not have the appropriate molecular characteristics to be used as a general assay. Our personal experience has been that the solvent used to extract the tannins may interfere with the hemoglobin precipitation. In addition, only veinous and not arterial blood was appropriate for use, and only fresh blood (not frozen) could be used. The concept as presented by Bate-Smith (1973) appeared simple but in practice was complicated.

A radial diffusion technique for tannin precipitation has been developed (Hagerman, 1987). This method is a simple and rapid procedure, but has the disadvantages of being semiquantitative and requires previous knowledge of the specific tannin-protein interactions.

Near Infrared Reflectance Spectroscopy (NIRS)

Utilization of NIRS for analysis of agricultural commodities has been in practice since the early 1970's. The benefit of NIRS is that once a suitable reference method is established for its calibration, the technology provides a rapid and non-destructive way to estimate chemical constituents. Analysis of tannins in lespedeza by NIRS has been demonstrated by Windham et al (1988). Their procedure of calibration was based upon acid-vanillin assays of oven-dried samples extracted with methanol. Further investigation of extraction and sample preparation procedures (discussed above), suggests the reference method used may not have been appropriate.

Since the initial investigation, other reference methods have been tested for NIRS estimation of tannins in lespedeza (Petersen et al., 1988). Oven-dried leaves from the Auburn University lespedeza breeding population were scanned. From these, samples with unique

NIR spectra were selected for a calibration set. Tannin was determined on the calibration set using three analytical procedures. Tannins were extracted from: 1) fresh-frozen lespedeza leaves using 70% acetone as the solvent; 2) oven-dried lespedeza leaves using 70% acetone as the solvent; and 3) oven-dried lespedeza leaves using 100% methanol as the solvent. Standard errors of calibration and prediction were lowest for the methanol extraction procedure, and gratest for the acetone extraction of the fresh-frozen leaves (Table 4). However the

Table 4. Calibration and validation statistics for reference methods used to estimate tannins in lespedeza with NIRS.

Reference method†	Calibration Mean	SEC	R^2	CV(%)
	-- CE --			
Acetone-FF	198	36	0.91	18.3
Acetone-OD	103	21	0.93	20.4
Methanol-OD	34	11	0.80	31.2
	Validation			
	Mean	SEP	R^2	CV(%)
	-- CE --			
Acetone-FF	194	29	0.95	15.1
Acetone-OD	109	21	0.92	19.2
Methanol-OD	46	17	0.79	37.7

† FF=fresh-frozen, OD=oven-dried, Acetone=70% acetone in water, Methanol=100% methanol.

coefficients of variation were inversely proportional to the standard errors. Reasons for this inverse relationship were because of greater tannin extraction from the samples with acetone, and increased tannin extraction from fresh-frozen tissues compared to oven-dried. Therefore, lower standard errors were not necessarily related to accuracy of the estimate. This was confirmed when entries from the Auburn breeding program were analyzed in a replicated field experiment. Coefficients of variability were lower for estimates of the samples using NIRS calibrations from the fresh-frozen data. Correlation coefficients between fresh-frozen data and oven-dried data were greater when the oven-dried samples were extracted with 70% acetone (Table 5). Therefore, if chemical analysis of oven-dried samples are to be used for NIRS calibration, 70% acetone extractions are most likely to rank samples the same as the fresh-frozen analysis.

Table 5. Correlation coefficients for estimates of tannin using three reference methods for lespedeza harvested from 2 locations and 2 years.

Reference method	Acetone FF	Acetone OD	Methanol OD
Acetone-FF†	--	0.96	0.85
Acetone-OD		--	0.91
Methanol-OD			--

† See Table 4.

Progress In The Plant Breeding Effort

The history of the lespedeza breeding program at Auburn University was to select low-tannin lines utilizing the leaf-squash technique. As selected lines were advanced for testing in the program, the method used to analyze tannins was based on a water extraction of oven dried herbage (Donnelly and Anthony, 1983). In a cooperative experiment between Auburn University and the University of Georgia, breeding lines from the Auburn program were re-evaluated. The experiment involved 81 breeding lines, planted at two locations, and harvested in May and August in 1987 and 1988. Leaves from each harvested sample were stripped from the stems. The leaf samples were split in half, one-half frozen and the other dried at 65° C. Tannins were estimated by NIRS using tannins extracted from oven-dried samples with methanol or acetone, and 70% acetone extracts from fresh-frozen leaves as reference methods for calibration. Frequency distributions of the breeding lines for tannin concentration were generated for each method (Figure 1).

Data from samples which had been extracted with methanol suggests that progress has been made for selection of low-tannin lines of lespedeza. High tannin cultivars, added to the study as checks, tested high for tannin and cultivars which had been selected for low-tannin tested lower than the high-tannin lines (Figure 1a). A sister line of 'AU-Donnelly'

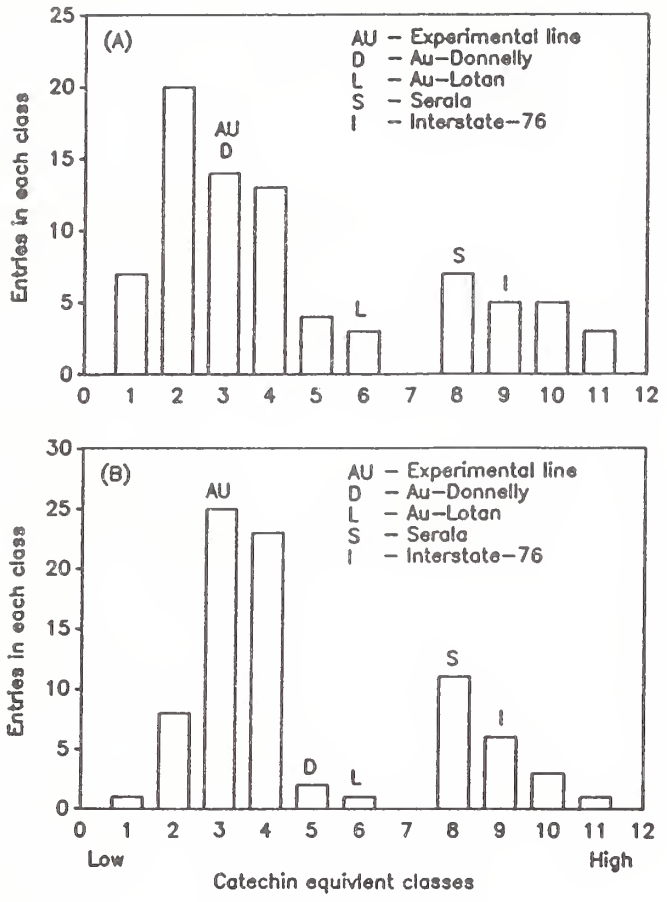

Figure 1. Frequency distribution of Auburn University lespedeza breeding lines for tannin content when extracted with methanol from oven-dried samples (A), or 70% acetone from fresh-frozen samples (B).

(marked with asterisk) tested similar for tannin content as AU-Donnelly. When predicted from the calibration for the fresh-frozen leaves, the sister line tested considerably lower in tannin content (Figure 1b). In addition, it appears that AU-Donnelly and 'AU-Lotan' are similar in tannin content. Yield data from this study suggests that agronomic performance of AU-Donnelly and it's sister line are similar. Therefore, because the appropriate technique was not used to select for low tannins in the breeding program, an opportunity was almost lost to investigate and develop the line which apparently has greater potential for improved animal performance.

CONCLUSIONS

The literature which addresses tannin analysis of herbage is confusing. Investigators should be cautious when selecting a method for analyzing tannins because these methods have not been thoroughly tested for their usefulness. The qualitative characteristics of tannins are not consistent with species and therefore extraction, sample preparation, and analysis procedures need to be investigated to determine that which is most appropriate. In lespedeza, tannins complex with proteins or oxidize when samples are dried. Consequently, tannin extraction is incomplete and may present misleading results when analyzing oven-dried samples. Analysis of fresh-frozen or freeze-dried lespedeza samples proved to be superior to oven-dried samples. Aqueous acetone (70%) provides more complete tannin extraction than acetone, methanol, aqueous methanol, or water. Implementation of NIRS analysis with improved reference methods permits rapid, more precise, and accurate estimates of tannins in herbage. The complexity of the improved analytical procedures for tannin estimation makes NIRS a critical component of any breeding program whose objective is to develop low-tannin cultivars in an efficient manner.

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PHENOLIC ACID CONTENT OF BERMUDAGRASS HERBAGE

M.A. Hussey and R.D. Waniska[1]

INTRODUCTION

The inhibitory role of lignin in the degradation of plant cell walls has been well documented. In recent years, a greater emphasis has been placed on simple phenolic monomers [phenolic acids (PA)], and their potential role in limiting cell wall digestibility. The exact mechanisms by which lignin and phenolic acids act to limit cell wall digestibility are unknown, but probably involve a combination of 1) encrustation (i.e. acting as a physical barriers to digestion), 2) formation of insoluble lignin-polysaccharide complexes, 3) microbial toxicity, and the 4) inactivation or inhibition of enzyme systems. The literature is further confounded because phenolic acids exist as cell solubles (Theander, 1981; Waniska et al., 1988), and are "weakly bound" to protein, cellulose, hemicellulose, pectin, and lignin being solubilized during digestion (Jung and Fahey, 1981; Waniska et al., 1988).

Lignin in plant cell walls, while highly variable in concentration, has been shown to increase with advancing maturity (Allison and Osbourn, 1970; Lindgren et al., 1980; Morrison, 1980; and Theander, 1981). This increase in total plant lignin is correlated with a reduced cell wall digestibility (Duble et al., 1972; Jung and Vogel, 1986). Bula et al. (1981) reported that for every 10 g kg^{-1} decrease in lignin, an increase of 40 g kg^{-1} *in vitro* dry matter disappearance (IVDMD) was observed. Therefore, selection for reduced lignin content should be expected to improve total cell wall digestibility.

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The brown mid-rib (bmr) character in sorghum is correlated with a lower lignin content. Cherney et al. (1986) have reported an increased cell wall IVDMD for bmr sorghum which had a 23% decrease in total cell wall lignin. Hanna et al. (1981) reported similar increases in IVDMD with total cell wall lignin reductions of 30 and 32% for bmr-12 and bmr-18 lines.

Further examination of total lignin composition using bmr sorghum mutants revealed an altered chemical composition with bmr mutants having an increased ferulic to p-coumaric acid ratio (Kuč and Nelson, 1964; Bucholtz et al., 1980; Akin et al., 1986; Cherney et al., 1986). Studies with tall fescue have confirmed the inhibitory nature of increased p-coumaric acid content in cell walls. Akin et al. (1987) reported that tall fescue grown at high temperature (30/27°C) had a reduced ferulic acid to p-coumaric acid ratio. The increase in p-coumaric acid was directly related to a decreased cell wall digestibility.

The inhibitory nature of soluble phenolic acids has also been demonstrated. Phenolic compounds are known to interfere with the isolation of enzymes, presumably by binding to proteins in a manner similar to that reported for tannin-protein complexes (McManus, 1981). The addition of p-coumaric acid to rumen microorganism cultures inhibited the growth of cellulose degrading organisms (Akin, 1982), while ferulic and sinapic acids had limited influence on microbial growth. While the exact mechanism of microbial inhibition was not studied, phenolic acids are thought inhibit microbial growth presumably through membrane damage and lysis of bacteria (Jurd et al., 1971; Davidson and Branen, 1981).

The direct inhibition of enzyme activity by soluble phenolic acids has also been demonstrated for mammalian and plant systems. Van Sumere et al. (1975) demonstrated that caffeic, ferulic, gallic, and syringic acids inhibited pancreatic RNAase activity. Similarly, phenolic fractions isolated from alfalfa have been shown to inhibit trypsin,

lipase, and amylase activities (Milic et al., 1972). Waniska et al. (1988) demonstrated that the addition of phenolic acids inhibited alpha- and gluco-amylase activity and that the levels of free phenolic compounds in the leachate of ensiled sorghum were high enough to inhibit the hydrolysis of polysaccharides.

While phenolic acids have been shown to decrease forage IVDMD, and inhibit microbial growth and enzyme systems, little research has been conducted to look at the distribution of phenolic acids in perennial forages. Therefore, the objective of this study was to quantify the distribution of free and bound phenolic acids in irrigated bermudagrass.

MATERIALS AND METHODS

Forage samples from a previously established plot of 'Brazos' bermudagrass (Cynodon dactylon (L) Pers.) were obtained over a 2 yr period. Prior to each period, the plot area was harvested using a flail-type mower to remove standing herbage and all plots fertilized with 150 kg N ha^{-1}. Individual plots (1.5 m^2) were established in a randomized complete block design consisting of 6 and 4 replications in 1987 and 1988, respectively. Within each year, regrowth was monitored beginning of April, June, and August. Supplemental irrigation was applied weekly during both years.

Forage samples were harvested at 4 d intervals in 1987 and at 7 d intervals in 1988 resulting in a total regrowth period of 40 or 42 days in 1987 and 1988, respectively. Herbage samples (0.25 m^2) were harvested at ground level using electric clippers. A portion of each plot (ca. 30 percent) was hand separated to provide lamina, stem (+ leaf sheath), and dead herbage fractions. All samples were dried at 50°C, ground in a Wiley mill to pass a 2mm screen, reground through a 1mm screen using a Udy Mill, and frozen prior to laboratory analysis.

Free phenolic compounds were extracted with 1% hydrochloric acid in methanol (Waniska et al., 1988). Bound phenolic compounds in the remaining plant material was hydrolyzed and solubilized using 4.0 N NaOH. Phenolic compounds in the hydrolizate were then extracted with ethylacetate after the solution is acidified to pH 2. The ethylacetate was rotoevaporated and the phenolic acids solubilized in methanol. Both extracts (free and bound phenolic constituents) were analyzed using the Folin-Ciocalteu (FC) and the HPLC methods. The FC method determines the amount of soluble aromatic compounds that contain an hydroxyl group (i.e. phenolic compounds), while the HPLC method separates and quantitates soluble phenolic monomers, e.g. p-coumaric, ferulic, etc. A C-18 reverse phase column was eluted with a multi step gradient of 2% acetic acid in water to 10% n-butanol in methanol.

RESULTS

Herbage mass was determined during May-June, June-July, and August-September over a 2 year period (Table 1). A mean of 2304, 4176, and 7594 kg ha^{-1} was obtained for lamina, stem, and whole plant (total forage) samples harvested a 42 d intervals. Live lamina accounted for approximately 30% of the total dry matter produced with stems (ca. 55%) and dead leaves (ca. 15%) accounting for the remaining herbage.

Table 1. Herbage mass of irrigated Brazos bermudagrass harvested at 42 d intervals (2-yr average).

	May-June	June-July	Aug.-Sept.
	----------kg ha^{-1}----------		
Lamina	2122 a	2381 a	2409 a
Stem	4256 a	4806 a	3467 b
Whole Plant	7161 b	8520 a	7147 b

[1] Means within a row followed by the same letter are not significantly different (p=0.05).

Extraction techniques utilized in this study permitted the partitioning of PA's into "free" (acidic methanol soluble fraction) and "bound" (NaOH soluble fraction) components. We were able to consistently identify 8 PA's in all bermudagrass tissue types. Arranged in order of increasing retention time, these PA's consisted of gentisic (GEN), p-hydroxybenzoic (POH), vanillic (VAN), caeffic (CAF), p-coumaric (COU), ferulic (FER), salicylic (SAL), and cinnamic (CIN) acids.

No consistent seasonal trend was observed for the sum of free or bound PA's. Averaged over years, harvest periods and tissue types, approximately 94% of the PA content of bermudagrass herbage was present in the "bound" (NaOH soluble) form.

The PA composition of 42 d leaf tissue is presented in figures 1-2. Free PA content ranged from 9-578 ug g^{-1}, with CAF, COU, FER, GEN, and SAL occurring at concentrations greater than 90 ug g^{-1}. P-coumaric and FER were the predominant bound PA's in leaf tissue and accounted for approximately 80% of all PA's identified.

The PA content of stem tissue is presented in figures 3-4. Stem tissue was observed to contain approximately 50%

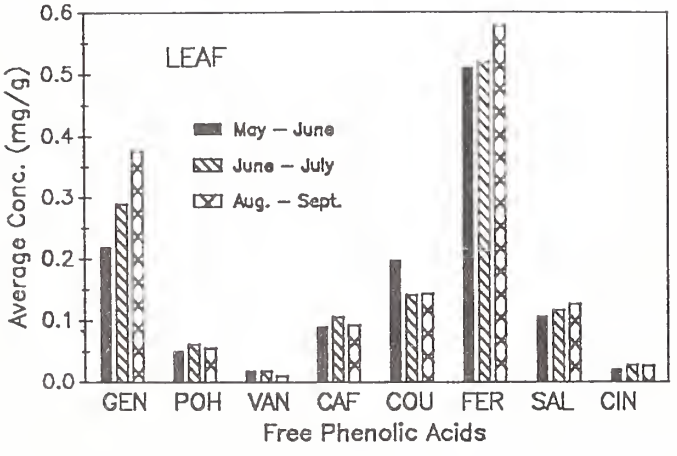

Figure 1. Seasonal trends of free phenolic acids in bermudagrass leaf tissue.

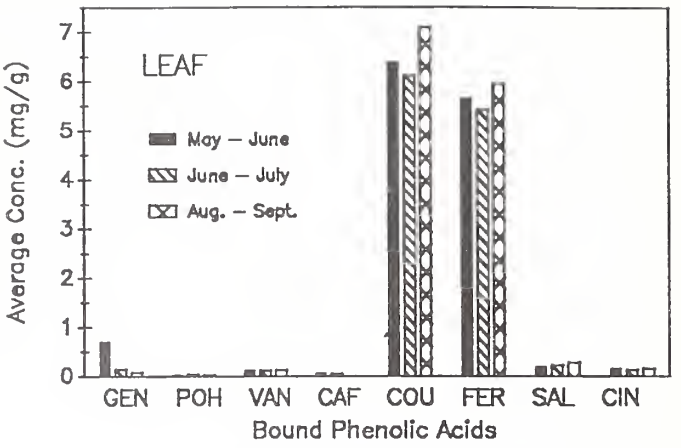

Figure 2. Seasonal trends of bound phenolic acids in bermudagrass leaf tissue.

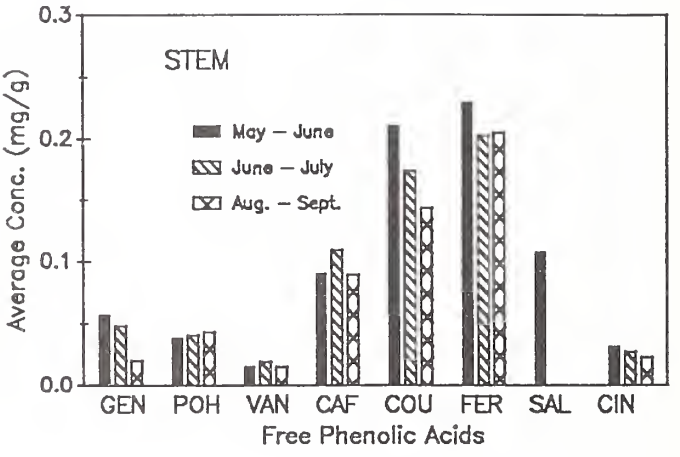

Figure 3. Seasonal trends of free phenolic acids in bermudagrass stem tissue.

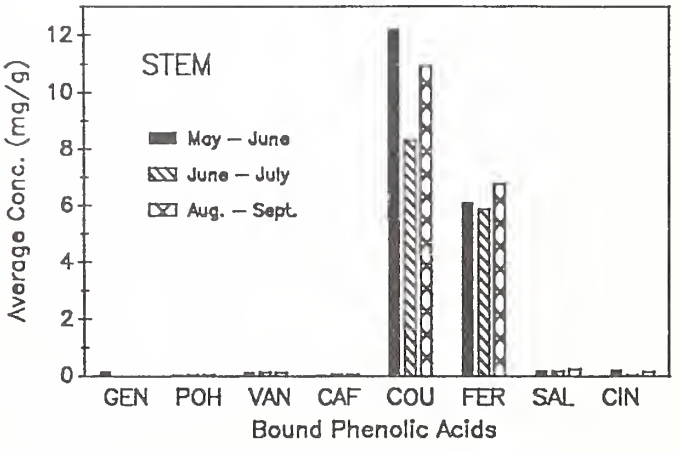

Figure 4. Seasonal trends of bound phenolic acids in bermudagrass stem tissue.

less free PA's than leaf tissue. Free PA content ranged from 15-230 ug g^{-1} with CAF, COU, and FER occurring at concentrations greater than 90 ug g^{-1}. The bound PA content of stem tissue was approximately 10% less than observed for leaf tissue. P-coumaric and FER were again the predominant PA's accounting for 92% of the total bound PA content.

Free and bound PA concentrations were influenced by maturity of the tissue. Free PA content of whole plant tissue was maximum at day 14 (4.5 mg g^{-1}) and declined with increasing plant age; however, no change was observed in the content of free COU or FER during maturation (Figure 5).

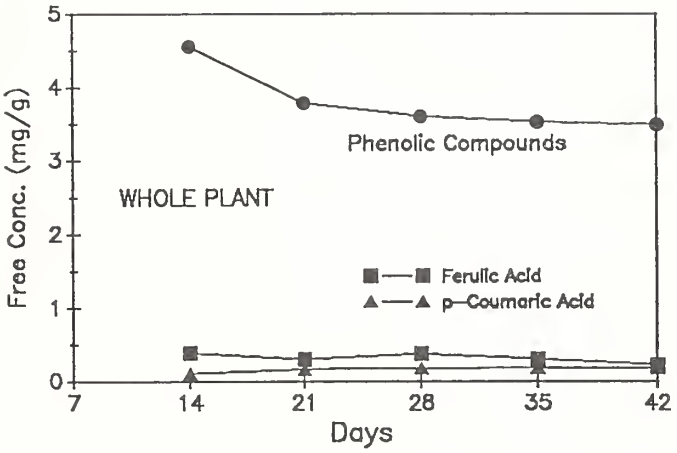

Figure 5. Influence of plant maturity on free phenolic acids and compounds in bermudagrass.

In contrast to the free PA's, total bound PA's increased with advanced maturity (Figure 6) with a maximum PA concentration being observed between days 21 and 28. Increases in COU and FER concentration were also observed with advancing maturity. These changes in the bound PA content were related to changes in plant morphology since maximum stem production occurred between days 21-35.

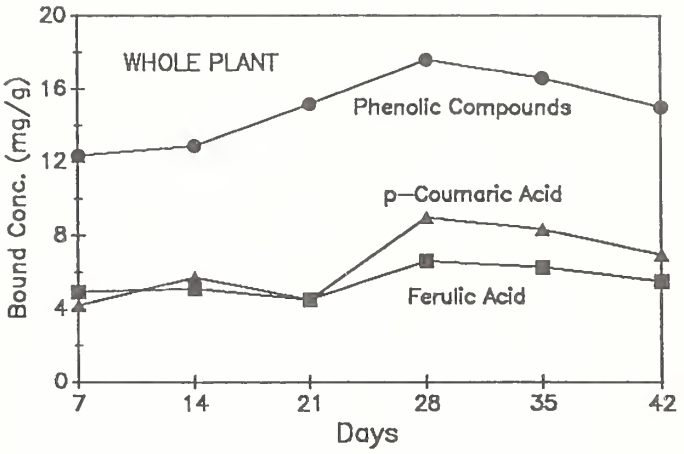

Figure 6. Influence of plant maturity on bound phenolic acids and compounds in bermudagrass.

DISCUSSION

Previous research has indicated a decline in forage IVDMD with increasing maturity. This decline may be attributed to greater cell wall contents, lignification, and ratios of p-coumaric to ferulic acid. In this study, an increase in total PA concentration and ratio of COU:FER was observed with advanced maturity. Preliminary IVDMD determinations have not shown a significant relationship between PA content and digestibility (data not shown).

This research represents the first step toward studying the potential inhibitory role of PA's in bermudagrass. Subsequent investigations will be directed toward understanding the mechanisms by which PA's act to inhibit enzyme systems in vitro.

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ISOFLAVONES IN ANNUAL CLOVERS

G. R. Smith

Isoflavone phyto-estrogens are compounds that occur naturally in several Trifolium species. These compounds are associated with reproductive disorders in sheep (Bennetts et al., 1946). Isoflavones identified in subterranean clover (Trifolium subterraneum L.) include formononetin (7-hydroxy-4'-methoxyisoflavone; FM), genestein (5,7,4'-trihydroxyisoflavone; GE), biochanin A (5,7-dihydroxy-4'-methoxyisoflavone; BA), and trace amounts of daidzein (7,4'-dihydroxyisoflavone; DA) (Guggolz et al.,1961). These compounds also occur in subterranean clover in bound or glycoside forms (Beck, 1964).

Formononetin is the most potentially damaging compound for both sheep and cattle, based on research to date. Formononetin is demethylated and reduced to equol (7,4'-dihydroxyisoflavan) by ovine and bovine rumen microflora (Nilsson et al.,1961; Shutt and Braden, 1968; Batterham et al.,1971; and Dickinson et al.,1988). Equol is absorbed from the gastrointestinal tract, and high blood concentrations are responsible for infertility in sheep (Lindner, 1967). In bovine rumen fluid the metabolism of FM produced DA and equol but the only product of BA was GE (Dickinson et al., 1988).

DETECTION AND QUANTIFICATION METHODS

Beck (1964) described techniques for extraction and detection of isoflavones from subterranean clover using thin-layer chromatography. Francis and Millington (1965) modified these methods for use as a rapid screening assay in plant breeding. Several methods to quantify isoflavones from plant tissue using high performance liquid chromatography (HPLC) have been described recently.

Patroni et al. (1982) extracted ground subterranean clover leaves in ethanol for 10 min at 60C. The extract was applied to C-18 cartridges and eluted with methanol. Reverse phase HPLC using a C-18 column, methanol-water (27:73) mobile phase, and absorbance detection at 254nm separated and quantified FM, BA and GE. Nicollier and Thompson (1982) used similiar HPLC methods to separate and quantify methanol extracts (5C, 7 days) of subterranean clover leaves. Smith et al. (1986) modified the methods of Nicollier and Thompson (1982) to enhance peak shape and separation. Gildersleeve et al. (1989) reported a new reverse phase HPLC method using an Ultrasphere-ODS C-18 column with a 35% to 65% methanol gradient over 20 min following a 2 min delay. Isoflavones were detected using an HP 1040A photodiode array detector.

HARVEST DATE AND SEASON

Formononetin levels increase during leaf development of subterranean clover, peak at the fully expanded stage and decline in expanded leaves during plant growth (Rossiter and Beck, 1967). Isoflavone levels measured in subterranean clover harvested in March, April and May declined over the season but rankings were generally the same (Smith et al., 1986). Gildersleeve et al. (1989) noted no significant harvest date effects when comparing five subterranean clover cultivars over three years. Year effects were noted but the rankings of FM, BA, GE and total isoflavones were consistent from year to year.

In a study designed to develop a seed or young seedling isoflavone assay for annual clovers, Gildersleeve et al.

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(1989) reported that the isoflavone content of 42 day old greenhouse subterranean clover seedlings was closely related (r=0.87) to that of field grown clover plants. The isoflavone content of ungerminated seed and young seedlings was low and highly variable.

SAMPLE STORAGE

Subterranean clover samples dried at 40C for 48 hr were 30 to 50% lower in total isoflavones than samples frozen at -12C or processed fresh (Smith et al., 1986). Glycoside forms of the isoflavones were reduced in frozen samples, possibly due to cell rupture and partial enzyme hydrolysis. Total FM in fresh subterranean clover tissue could be estimated very reliably (r^2=0.93) from measurements of free FM in samples frozen (-12C) for 24 weeks.

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FORAGE UTILIZATION INFORMATION EXCHANGE GROUP

AMMONIATED HAY TOXICITY UPDATE - CAUSES, SYMPTOMS AND PREVENTION.

H. Werner Essig[1]

Livestock producers are continually searching for ways to improve low quality stored roughages. The use of anhydrous ammonia at 3% of the DM has been demonstrated as being an inexpensive method of increasing crude protein, feed consumption, in vitro digestibility, animal gain, feed efficiency, and preventing spoilage (Moore et al., 1982; Vestal, 1982; Church, 1983; Grother et al., 1983; Stallcup et al., 1983; Hankins, 1984). The Ammoniation process has been accomplished under black plastic and in thermoammoniation chambers at a cost of less than $15 per ton (Horn et al., 1983; Essig et al., 1986). Ammoniated hay is not the perfect feed source. When the thermoammoniation process reaches a temperature above 70° C there appears to be an asssociation with cattle showing signs of toxicity (Perdock and Ling, 1985).

Many names have been associated with the toxic syndrome such as: ammoniated hay toxicity; hyperexcitability; crazy-cow syndrome; bovine hysteria; hyper-activity; bovine bonkers; locoing; neurological syndrome; hysteria; going crazy and stimulation (Perdock and Ling, 1985). Reported symptoms are: cow aborts; calf death (2 to 24 d of age); cow delirium; diahrrea; hyperactivity; circular movements; running into obstacles; incoordination (loss of balance); quivering of ears and flanks; restlessness; rapid eye blinking; dilation of pupils; bellowing; impairment of vision; frequent urination and defecation (black sticky feces); rapid respiration; salavation; frothing of the mouth; coma, and convulsions (Eng, 1986; Perdock and Ling, 1985; Essig et al., 1986).

A survey of Animal Science Departments in 50 states plus Puerto Rico was conducted in 1985 to assess problems and incidence of ammoniated hay toxicity. There were 35 responses, 25 indicated no problem, 10 states indicated there had been incidence of hyperexcitability, prenatal and postnatal calf deaths in producer herds. There were two states where observations were reported to have occured at Experiment stations (one station in Ohio and two stations in Mississippi). Since the survey symptoms have been observed at an Experiment station in Texas (W.R. Cumpaugh, personal communication).

Ammoniated hay toxicity has been reported mostly by producers. They have reported the toxicity symptoms to occur in animals fed fescue, brome, wheat, ryegrass, bermudagrass, grass-legume, sudan, and hegari hay. Toxicity has occured in animals fed high and low quality hays. Perdock and Ling (1985) have produced the toxicity symptoms on wheat straw, rice straw and other low quality forage. The kind or quality of hay does not appear to be associated with causing ammoniation toxicity symptoms.

Toxicity symptoms observed at Mississippi State University occured in February of 1985 in two of five cow herds being fed ammoniated hay (Essig et al., 1986). In one herd showing symptoms two calves lived of 16 born (6 DOA - 6 Died in 1 to 24 d). In the other herd showing toxicity seven calves lived, six were DOA and 4 died (in 2 to 8 d).

Three trials were conducted to measure the influence of: 1. three ammonia levels at four temperatures; 2. three moisture levels at four temperatures and; 3. three lengths of heating time at four temperatures. The only treatment to consistantly produce hyper-

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excitability was using anhydrous ammonia at 3% of DM of the hay while heating the hay at 100° C for 61 hr using the Anstraverter chamber. This hay treatment procedure was used to evaluate possible methods of prevention of hyperexcitability.

In trial 4 the hyperexcitability provocative hay was used as a control. Other treatments were: control plus 1 g thiamin per 190.7 kg body weight at 7 day intervals; control plus 1.36 kg ground shelled corn; control hay fed at the same level of a paired animal in treatment 3 (hay without corn); control plus listeriosis bactrin (im on the first day of the trial); and control plus 146 g MgO_3 per 7 days (in a gelatin capsule). Symptoms of hyperexcitability occured in animals on all six treatments.

Trials 5 and 6 evaluated the same treatments with trial 5 being conducted in June-July and trial 6 being conducted in Oct-Nov. Nine treatments were used in both trials: control (thermo-ammoniated hay) plus 2 lb of ground shelled corn; control plus $CuSO_4$ at 13 g daily; control plus 100 g $NaHCO_3$ daily; control plus 3.25 g thiabendozole daily; control plus 300 mg monensin daily; control plus 360 mg of lasalocid daily; control plus 300 mg salinomycin daily; control plus 200 mg of virginiamycin daily; and control hay reheated at 100° C for 61 hr. The monensin, $NaHCO_3$, TBZ, $CuSO_4$, lasalocid, salinomycin and virginiamycin were all supplied as a mixture in 2 lb of corn . In trial 5 there were no obvious symptoms of hyper-excitability. In trial 6 the first symptoms of hyperexcitability were observed on day 3 with 23% of steers showing symptoms. By day 10, 58% of the steers had demonstrated hyper-excitability signs and by day 23 81% of the steers had demonstrated hyperexcitability symptoms. Only one incidence of hyperexcitability was observed in the five steers given virginiamycin. Feed intake was generally lower in trial 5 than in trial 6, suggesting that the ambient temperature influence on feed intake may trigger symptoms of hyperexcitability.

It was hypothesized that high internal heat (about 70C) of large round bales from baling to about 6 wk may contribute to producing an ammoniated hay that may cause hyperexcitability. It was reasoned that if hay has gone through the post baling heat it may produce a less toxic ammoniated hay. A study was conducted where hay was baled and placed under black plastic within 3 days of baling and ammoniated at either 3 or 1.5% of the DM. A second group of bales were placed under covered storage for 6 wk before being ammoniated at 3 and 1.5% of DM. A third group of bales were stored under shelter until time of feeding where the bales were thermo-ammoniated in a chamber at 3 and 1.5% of DM for 61 hr. Two studies were conducted from January to May in 1988 and 1989. In 1988, seven of the eight steers fed the hay thermoammoniated at 3% of DM for 61 hr exhibited symptoms of hyperexcitability and one steer fed stored hay ammoniated at 3.0% of DM under black plastic showed symptoms of hyperexcitability. In 1989, no symptoms of hyperexcitability were observed. The temperatures from January to May 1989 were much higher with no prolonged periods of cold weather and is suggested as the cause of no hyperexcitability in 1989.

CONCLUSIONS

Hyperexcitability is not dependent on ammonia levels, moisture level, kind or quality of hay, but is dependent upon prolonged high heat during the early ammoniation process. Hyperexcitability can be produced by feeding hay that has been processed using anhydrous ammonia at 3% of DM at temperatures of 100° C for 61 hr. Treatments having no influence on prevention of hyperexcitability were: corn, thiamin, listeriosis bactrin, magnesium oxide, sodium bicarbonate, thiabendazole, monensin,

lasalocid, copper sulfate and salinomycin. Virginiamycin appeared to decrease the incidence of hyperexcitability more than any of the other compounds tested. Efforts should be made to minimize heat in bales at the time of ammoniation. Feed consumption at less than maximum intake, without influence of cold weather, may result in no hyperexcitability. Perhaps ammoniation under black plastic should be performed using stored hay (6 wk) sources during cloudy days, at night or during cool periods to help reduce incidences of hyperexcitability.

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USE OF AMMONIATED HAY - ANIMAL PERFORMANCE

W. F. Brown[1]

We have been interested in improving the feeding value of tropical forages primarily because most of the hay made by Florida livestock producers is not of adequate quality to meet the nutrient requirements of lactating cows or growing calves. In an extension forage testing program, Moore et al. (1984) determined that the average crude protein (CP) concentration of hay made by Florida livestock producers was 7.4%, with only 21% of the samples greater than 10% CP (Table 1). Bermudagrass and stargrass tended to be greater in CP than other tropical grass hays; however, only 33 and 25%, respectively of those samples were greater than 10% CP. Digitgrass and bahiagrass hays were low in CP, with only a few samples containing greater than 10% CP. Characteristically, limpograss contained less CP than other tropical grasses. Many bermudagrass and stargrass hay samples were submitted by the horse industry, suggesting that some of these samples were harvested at an earlier stage of maturity compared to other tropical grass hays.

Less variation existed in mean total digestible nutrient (TDN) content among livestock producer hays, with an average value of approximately 50% TDN (Table 2). Limpograss, which was lowest in CP, tended to be greater in TDN compared to other tropical grass hays.

Improved nutritive value of hay and animal performance can be obtained by feeding a less compared to a more mature forage (Table 3). Stargrass (Cynodon nlemfuensis Vanderyst var. nlemfuensis) hay harvested after 5 weeks regrowth was greater in CP concentration and in vivo organic matter (OM) digestibility, compared to hay harvested after 10 weeks regrowth. Crude protein concentration of the 5 week hay approached protein requirements of lactating cows and developing heifers, although observations from our laboratory and those of Anderson et al. (1988) suggest that up to 25% of total protein can be soluble in the rumen.

Table 1. Crude protein concentration of hay made by Florida livestock producers.

Hay[a]	Mean	Distribution (%) <6	6-10	>10
All	7.4	35	44	21
Bermuda	8.8	16	51	33
Star	8.1	24	51	25
Digit	5.2	74	24	2
Bahia	6.6	41	56	3
Limpo	4.0	83	17	0

[a]All = all samples combined, Bermuda = Cynodon dactylon, Star = Cynodon nlemfuensis, Digit = Digitaria decumbens, Bahia = Paspalum notatum, Limpo = Hemarthria altissima.

Source: Moore et al. (1984).

Table 2. Total digestible nutrient content of hay made by Florida livestock producers.

Hay[a]	Mean	Distribution (%) 40-45	45-50	50-55	55-60
All	49	12	45	39	4
Bermuda	49	11	48	37	4
Star	50	9	37	47	7
Digit	49	7	48	44	1
Bahia	47	31	59	10	0
Limpo	54	0	4	71	25

[a]See footnote in Table 1.

Source: Moore et al. (1984).

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Table 3. Nutritive value and growth performance of heifers fed stargrass[a] hay at two regrowth intervals.

Item[b]	Regrowth, wks 5	10	SE[c]
Crude protein	10.6	4.4	
OM digestibility	57.7	48.5	1.56
Daily feed, kg DM	4.3	2.9	.34
Daily gain, kg	.22	.01	.040

[a]Cynodon nlemfuensis Vanderyst var. nlemfuensis.
[b]OM = organic matter, DM = dry matter.
[c]SE = standard error of the mean.

Source: Brown (1988).

Yearling Brahman crossbred heifers placed on bahiagrass (Paspalum notatum) pasture during the winter ate more of the 5 week compared to the 10 week hay (Table 3). The additive effect of increased intake and improved OM digestibility resulted in a dramatic increase in daily gain for cattle fed less compared to more mature hay.

A practical economic-based question arises as to whether the poorer quality forage should be accepted and then supplemented with energy and/or protein, or whether improved quality forage should be produced. Increased hay yield can be obtained by accepting poor quality forage, and weather conditions do not always allow for proper management to obtain 5 week regrowth hay. In unpublished data, Dr. J. E. Moore (personal communication) evaluated energy supplementation of a lower and higher quality bermudagrass (Cynodon dactylon) hay. Steer calves fed the lower quality hay alone gained no weight during the winter feeding period. Energy supplementation of the lower quality hay resulted in daily gain equal to that obtained from the higher quality hay alone. However daily gain obtained from feeding the lower quality hay plus supplement, the higher quality forage alone or the 5 week hay presented in Table 3 is not adequate to develop weaned heifers so that they will be ready to calve for their first time at two years of age. Energy supplementation of the higher quality forage resulted in performance that would be acceptable for heifer development. Therefore, when feeding cattle with high nutrient requirements such as developing heifers, greater levels of energy and/or protein supplementation may be required when the basal forage is low in quality. As supplementation level increases in combination with a low quality forage, the diet becomes less forage-based. An improved quality forage can form a base to which supplementation programs may be applied. However, convincing Florida livestock producers to accept reduced hay yield in order to obtain improved quality hay is very difficult. Because of this we have concentrated on improving the feeding value of tropical grass hay by chemical treatment.

MATURITY X AMMONIATION

In many cases poor weather conditions do not allow grasses to be harvested for hay after 5 weeks regrowth. In this case large quantities of poor quality forage accumulate. A practical question arises as to whether a 5 week regrowth hay should be harvested if possible, or whether forage growth should continue to obtain additional yield, and the poor quality forage treated with anhydrous ammonia to improve its feeding value.

Two digestion and growth trials were conducted to evaluate the influence of forage maturity and ammoniation on the feeding value of stargrass hay (Tables 4 and 5; Brown, 1988). From a nutritive value standpoint, increased CP concentration of ammoniated compared to untreated forage as a result of non-protein nitrogen (NPN) addition is not a major advantage of ammoniation. From an economic standpoint in Florida however, this is an important consideration because standard molasses at approximately $75/ton can be fed with ammoniated hay rather than a urea-fortified molasses at approximately $120/ton. Ammoniation reduced neutral detergent fiber (NDF) and acid detergent lignin (ADL) concentrations of both hay maturities. Both in vitro organic matter digestion (IVOMD) and in vivo OM digestibility were increased by ammoniation in both hay maturities; however, responses were greater in more compared to less mature hay.

Table 4. Chemical composition, digestibility and growth performance of steers fed stargrass[a] hay at two regrowth intervals, either untreated or ammoniated.

Item[b]	6 wk regrowth		12 wk regrowth		SE
	Untreated	Ammoniated	Untreated	Ammoniated	
CP	6.9	13.8	4.4	8.1	
NDF	86.3	77.2	87.4	82.2	
ADL	6.8	4.8	7.8	7.3	
IVOMD	42.2	55.5	30.8	50.6	
OM digestibility	52.2[d]	59.8[e]	42.9[c]	56.2[e]	1.48
Daily feed, kg DM	5.4[d]	5.1[d]	4.6[c]	5.5[d]	.17
Daily gain, kg	.27[d]	.33[de]	.14[c]	.41[e]	.034

[a]Cynodon nlemfuensis Vanderyst var. nlemfuensis.
[b]CP = crude protein, NDF = neutral detergent fiber, ADL = acid detergent lignin, IVOMD = in vitro organic matter digestion, OM = organic matter, DM = dry matter.
[cde]Means in the same row without a common letter in their superscripts differ (P<.05).

Source: Brown (1988).

Table 5. Chemical composition, digestibility and growth performance of heifers fed stargrass[a] hay at two regrowth intervals, either untreated or ammoniated.

Item[b]	5 wk regrowth		10 wk regrowth		SE
	Untreated	Ammoniated	Untreated	Ammoniated	
CP	10.6	14.4	4.4	9.4	
NDF	85.0	74.0	87.6	80.1	
ADL	7.0	5.5	8.3	8.1	
IVOMD	46.5	58.2	35.0	45.7	
OM digestibility	57.7[d]	63.7[e]	48.5[c]	62.1[e]	1.56
Daily feed, kg DM	4.3[d]	4.9[d]	2.9[c]	5.0[d]	.34
Daily gain, kg	.22[d]	.38[e]	.01[c]	.34[e]	.040

[abcde] See footnotes in Table 4.

Source: Brown (1988).

A significant interaction also existed between maturity and ammoniation for animal performance (Tables 4 and 5). The trial reported in Table 4 utilized Brahman crossbred steers (198 kg) fed in drylot during their first winter following weaning. Hays were ground through a 5-cm screen. Diets consisted of approximately 85% hay and 15% supplement, and were fed in ad libitum quantities once daily in a covered bunk. Natural protein was present in the supplement. The trial reported in Table 5 utilized Brahman crossbred heifers (205 kg) fed on bahiagrass pasture during their first winter following weaning. Hays were fed in ad libitum quantities in the round bale form in round bale feeders. A cottonseed meal based supplement (.45 kg/head/day) was also fed.

In both trials, ammoniation of the less mature hays did not increase feed intake, while increased intake was observed by ammoniation of the more mature hays (Tables 4 and 5). In Table 4, ammoniation of more mature hay improved daily gain by approximately 200% ($P<.05$), but ammoniation of less mature hay resulted in a nonsignificant increase in daily gain of 22%. In Table 5 ammoniation improved daily gain of heifers fed both hay maturities, but the response was greater in more compared to less mature hay. Feeding value of the more mature ammoniated hay was similar to or improved compared to that of the less mature untreated hay.

Ammoniation has the potential to improve the feeding value of tropical grass hay, although response is greater in more mature compared to less mature hay. Hay harvested after 4 to 6 weeks regrowth probably should be fed untreated. If hay harvest is delayed, feeding value of the resulting more mature lower quality forage can be made similar to that of a less mature untreated forage by ammoniation.

AMMONIATION OR SUPPLEMENTATION

A common winter feeding program in Florida for lactating cows and developing heifers involves cattle on frosted bahiagrass pasture, and fed low quality hay plus a urea-fortified molasses. Because of this low level of winter feeding, pregnancy rates in cows are often low, and most heifers do not calve for their first time until three years of age. We wanted to compare animal performance obtained from feeding ammoniated hay to animal performance obtained from a common winter feeding program of untreated hay plus molasses-urea.

The trial shown in Table 6 utilized mature limpograss (Hemarthria altissima) hay fed alone or supplemented with molasses, or ammoniated. Brahman crossbred steers (220 kg) were fed in drylot during their first winter following weaning. Hays were ground through a 5-cm screen. Diets consisted of approximately 90% hay, 10% supplement for the untreated hay alone and ammoniated hay alone diets, and approximately 65% hay, 25% molasses, 10% supplement for the untreated hay plus molasses diet. The supplement contained natural protein. The trial shown in Table 7 utilized the same treatments as those in Table 6 except rice straw was used instead of limprograss hay and initial weight of the Brahman crossbred steers was 277 kg.

In both trials, ammoniation increased forage concentration of protein and reduced concentrations of NDF and ADL (Tables 6 and 7). In vitro OM digestion was improved by approximately 40% by ammoniation. It was expected that molasses addition to untreated forage would improve overall dietary OM digestibility. However, OM digestibility was similar between the untreated forage alone and untreated forage plus molasses diets because NDF digestibility was reduced by molasses supplementation. This negative associative effect due to readily available carbohydrate supplementation has been observed in other situations (Mould et al., 1983). Preliminary observations from our laboratory suggest that molasses supplementation may not reduce NDF digestibility in higher quality (ammoniated) forages to the same extent that it does in lower quality (untreated) forages. Organic matter and NDF digestibilities of ammoniated forage were improved compared to untreated forage alone or untreated forage plus molasses.

In the growth trials, calves fed untreated forage plus molasses consumed more feed and gained more weight than calves fed untreated forage alone (Tables 6 and 7). Calves fed ammoniated

Table 6. Chemical composition, digestibility and growth performance of steers fed limpograss[a] hay alone, supplemented with molasses, or ammoniated.

Item[b]	Treatment			SE
	Untreated	Untreated + molasses	Ammoniated	
CP	3.2		10.3	
NDF	88.9		80.9	
ADL	9.4		8.8	
IVOMD	46.2		62.5	
OM digestibility	48.9[c]	47.9[c]	57.5[d]	1.15
NDF digestibility	57.0[d]	51.0[c]	68.7[e]	1.89
Daily feed, kg DM	4.3[c]	5.2[d]	5.2[d]	.43
Daily gain, kg	.27[c]	.39[d]	.54[e]	.09

[a]Hemarthria altissima.
[bcde]See footnotes in Table 4.

Source: Brown et al. (1987).

Table 7. Chemical composition, digestibility and growth performance of steers fed rice straw[a] alone, supplemented with molasses, or ammoniated.

Item[b]	Treatment			SE
	Untreated	Untreated + molasses	Ammoniated	
CP	5.6		11.0	
NDF	76.9		72.7	
ADL	7.6		6.6	
IVOMD	37.0		54.4	
OM digestibility	46.3[c]	47.8[c]	59.0[d]	1.58
NDF digestibility	51.9[d]	46.2[c]	73.0[e]	2.84
Daily feed, kg DM	5.2[c]	6.5[d]	6.7[d]	.23
Daily gain, kg	.23[c]	.41[d]	.40[e]	.040

[a]Oryza sativa.
[bcde]See footnotes in Table 4.

Source: Brown et al. (1987).

forage ate 20 to 29% more forage and gained 74 to 100% more weight than calves fed untreated forage. Calves fed ammoniated forage consumed similar amounts of feed compared to calves fed untreated forage plus molasses. Daily gain for calves fed ammoniated limpograss hay was greater than that for untreated hay plus molasses (Table 6), but daily gain was similar between ammoniated rice straw and untreated straw plus molasses treatments (Table 7).

Animal performance on ammoniated forage alone was at least as good as that obtained from untreated forage plus molasses. It is important to note that these diets were supplemented with natural protein, and that level of animal performance on the ammoniated forage or untreated forage plus molasses probably were not adequate for developing heifers. However, calves fed the ammoniated forage did not have access to energy supplement.

SUPPLEMENTATION OF AMMONIATED HAY

Ammoniation improves the protein concentration of hay through NPN addition from anhydrous ammonia. However, hay before treatment generally is 5 to 7% CP, and approximately 1.0 unit of this is acid detergent insoluble crude protein, and up to 25% of the remainder may be rumen soluble. From these observations it may be suggested that cattle with high nutrient requirements, such as developing heifers, may respond to natural protein. Ammoniation also improves TDN content of hay, increases hay intake by cattle, and the additive effect of increased TDN intake has a dramatic effect on animal performance. However, performance obtained from ammoniated hay alone is not adequate to develop heifers so that they will be able to calve for their first time at two years of age. For these reason we have been interested in energy and protein supplementation of ammoniated hay.

Brahman crossbred steers (220 kg) were placed on bahiagrass pasture after weaning and fed one of the four diets shown in Table 8. Ammoniated stargrass hay was fed in the round bale form in round bale feeders. Standard molasses was fed in ad libitum quantities in covered troughs. Cottonseed meal was fed at the rate of .45 kg/head/day. Molasses and cottonseed meal were fed on Monday, Wednesday and Friday.

Table 8. Growth performance of steers fed ammoniated stargrass[a] hay alone, or supplemented with molasses and/or cottonseed meal.

Item[b]	Ammoniated	Ammoniated + molasses	Ammoniated + CSM	Ammoniated + molasses + CSM	SE
Intake, kg DM					
Hay	5.9[d]	4.1[c]	5.5[d]	5.0[cd]	.26
Molasses		2.0[c]		2.4[c]	.21
CSM			.5	.5	
Total	5.9[c]	6.1[c]	6.0[c]	7.9[d]	.24
Daily gain, kg	.21[c]	.35[d]	.47[e]	.76[f]	.028

[a]Cynodon nlemfuensis Vanderyst var. nlemfuensis.
[b]DM = dry matter, CSM = cottonseed meal.
[cdef]Means in the same row without a common letter in their superscripts differ (P<.05).

Source: Brown (unpublished).

Calves supplemented with molasses had reduced hay intake compared to calves fed ammoniated hay alone (Table 8). We have observed this substitution effect on hay intake by molasses supplementation in previous trials. For the ammoniated hay plus molasses plus cottonseed meal diet, molasses and cottonseed meal were mixed into a slurry and fed. Previous observations suggest that molasses intake is increased when a dry feed is mixed with it. Molasses intake was increased when cottonseed meal was added, although differences were not significant (2.0 vs 2.4 kg; Table 8). Total feed intake was similar between the hay alone, hay plus molasses and hay plus cottonseed meal diets, but total feed intake was greatest for the hay plus molasses plus cottonseed meal diet.

Calves fed ammoniated hay alone gained .21 kg/day (Table 8). Therefore, this hay was adequate to meet maintenance requirements plus provide a level of gain, and could form a base for supplementation. Both molasses and cottonseed meal supplementation improved daily gain, but the protein response was greater than the energy response. At current prices (hay: $.06; molasses: $.11; CSM: $.37; per kg) cost of the added gain was less expensive for cottonseed meal ($.65/kg) than it was for molasses ($.86/kg). Calves fed ammoniated hay plus molasses plus cottonseed meal gained .76 kg/day. This level of animal performance is more than adequate to develop a weaned heifer from 205 kg to 300 kg during a 6 month winter feeding program before being exposed to a bull.

CONCLUSIONS

Most tropical grass hay is low in feeding value, and historically molasses-urea supplementation of this hay has not provided adequate nutrition for acceptable calving rates or heifer development. Ammoniation increases energy value of hay, increases hay intake by cattle, and the additive effect of increased energy intake has a dramatic effect on animal performance. In most cases, ammoniated hay can provide the level of nutrition required for calves to meet maintenance requirements plus provide a small amount of gain. This provides a base upon which supplementation programs can be developed. Most tropical grass hay produced in Florida will not meet the maintenance requirements of growing calves, which reduces the effectiveness of a supplementation program.

No cow-calf data were presented in this paper. Due to hyperexcitability and calf survival problems that have been observed in cows fed ammoniated hay (Weiss et al., 1986; Perdok and Leng, 1987), we recommend that ammoniated hay not be fed to cows 30 days before or after calving. Because of 60 to 90 day or longer calving seasons, feeding ammoniated hay in a cow-calf situation is limited to late-lactation.

If tropical grass hay can be harvested after 5 weeks regrowth, it should be harvested and fed untreated. This hay can be fed with proper supplementation to lactating cows and first-calf heifers. However, forage on a certain amount of land area should be allowed to grow to obtain additional yield. This hay can be ammoniated and with proper supplementation can be fed to weaned heifers, bull and steer calves, dry cows and cull cows.

Ammoniation has been used by some producers to enhance feeding value, and as a harvesting-storage aid. Forage is cut directly into a windrow and allowed to dry for as long as weather permits. Generally this ranges from 4 hours to 2 days. The forage, generally ranging in dry matter content from 35 to 70%, is baled and immediately ammoniated at 3 to 4% of the forage dry matter. No fermentation occurs and cattle readily consume the material. In this case, only two passes over a field are required, one to cut and one to bale.

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ELECTRONIC MEASUREMENT OF SHORT-TERM INTAKE AND GRAZING BEHAVIOR

James R. Forwood

INTRODUCTION

The beginning point in a grazing study is to determine if pasture species A promotes more rapid or greater overall weight gain than species B. A more thorough investigation, however, will attempt to uncover why performance differed between species. Were the differences due to the amount of forage available, its digestibility, animal preference, grazability (canopy structure) of the sward or other factors? Aside from the fact that these plant-animal measurements are labor intensive, animal based data such as intake and grazing behavior must be collected in a way which will not produce spurious data. Methods that require harassment of tester animals in order to dose with markers or collect feces may alter grazing patterns (and subsequently, intake) such that accurate data collection is not possible (Fisher et al. 1986).

Attempts have been made to overcome the short-comings of conventional methods by employing animal carried electronic devices (Horn and Miller, 1979; Stuth et al., Pattinson et al. 1981; Mosley, et al. 1987; Adams et al. 1987) for estimating intake and grazing behavior and these become more numerous with time.

Researchers are drawing much nearer to providing reliable, accurate and affordable grazing behavior electronic measurement devices, however, intake measurement by similar means remains much more challenging. The following studies outline our attempts to estimate herbage intake and grazing behavior with electronic telemetry devices.

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ELECTRONIC INTAKE MEASUREMENT

The original objective in building a device which could measure intake had two main criteria. These were: 1) that the device accurately measure or estimate forage intake and allow for direct weight, size or density measurement of each bolus, 2) the device be animal carried and easily implanted in the esophagus. Thus far, direct weight or dimension measurement of the bolus has not been achieved.

Instead, intake has been estimated based on the number of boli swallowed.

After working with several devices, an esophageal cannula was modified such that a small glass temperature-sensitive thermistor would contact swallowed boli as they passed down the esophagus (Forwood and Hulse, 1987). This device was later called the thermal conductance cannula (TCC). Early tests indicated that water swallowing and regurgitation phenomena could be discriminated against in the data.

In-house feeding trials with various levels of hay showed a positive linear relationship between the amount of hay consumed and the number of swallows (Fig. 1). Modifications were then made to allow each swallowing event to be sent via telemetry electronics over a distance of 0.5 - 1.0 mile from a transmitter on the animals' halter to a computer which tabulates data. At the time of this writing, there is no doubt that swallowing events can clearly be received from animals in the pasture. Design of the sending and receiving electronics has allowed for as many as eight (8) swallowing events to be recorded at once. Studies are being considered now as to how to verify intake while the experimental animal is on pasture.

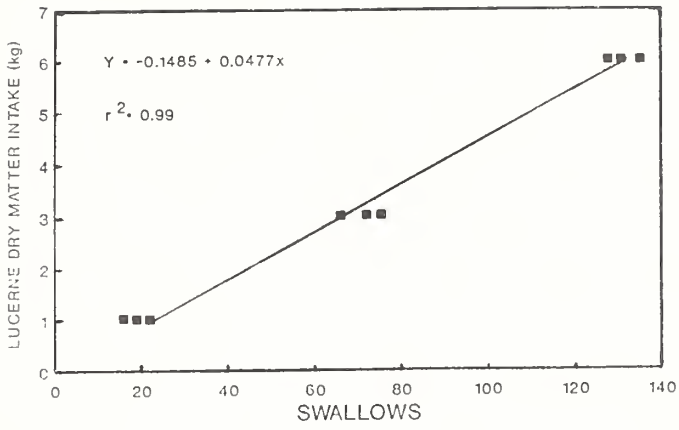


Fig. 1. Relationship of swallows to lucerne dry matter intake as detected by the thermal conductance cannula.

Before that step was taken, questions concerning factors that may alter bolus weight needed to be addressed. Two of the most important were the effects of animal weight (and/or size) and forage type on bolus weight. Obviously, if two animals of significantly different weights were to each swallow 100 boli, but boli from the heavier animal were several grams heavier than those from the smaller animal, their intakes would vary. The same would be true if the animals were grazing two distinctly different forages which resulted in different bolus weights.

Results from an outdoor study where light (360 kg) and heavy (553 kg) steers grazed fresh grass and from an indoor study where light (290 kg), medium (496 kg) and heavy (582 kg) steers were fed alfalfa hay, orchardgrass hay and a 50/50 alfalfa-orchardgrass mixture (Forwood et al. 1989) confirm that animal weight, forage maturity and forage species may affect bolus weight. Over all variables of the two studies, light steer average boli weights were 7.68 g while heavy steer boli averaged 17.3 g. Medium weight steers were used only in the indoor study and averaged boli of 15.1 g which was not different from large steer boli. These results indicate that steer weight differences of 86 kg or less will not likely result in boli weight differences. That explains the similarity of boli weights in a previous study where a maximum difference of 40 kg/cow body weight was present in the animals (Stuth and Angell, 1982). Although the data were variable, differences in boli weights of steers on different forage species, similar species and various maturity stages also resulted in varying boli weights but differences were not always significant. Sward characteristics such as total dry matter, leaf dry matter and bulk density and quality parameters such as in vitro organic matter digestibility, neutral detergent fiber, acid detergent fiber and crude protein were not well correlated with boli weight.

In general, as a result of these studies, the TCC is still questionable as a means of estimating intake. Additional studies are certainly required before it can be fully accepted. Esophageally fistulated animals may have to be maintained in order to calibrate the device for forage variables. Unfortunately, the elimination of fistulated animals and their associated health problems was an important goal in this work. It may still be possible to implant the thermistor itself next to the lumen of the esophagus using a very small incision.

One other problem worth mentioning is that some forages do not produce well defined boli. It has been reported that steers grazing some southern forage grasses (flaccidgrass for example) will exude a continuous stream of extrusa which defeats the theory of a device such as the TCC.

ELECTRONIC MEASUREMENT OF GRAZING BEHAVIOR

Grazing time (GT) and other grazing behavior measurements give clues as to how livestock are reacting to various swards and may lead to management and weight gain improvements. Grazing time, perhaps the most often measured behavior on pasture, is also one component of the equation estimating intake [Intake = GT x bite rate (BR) x bite size (BS)] which may receive widespread use if one day all of the variables could be rapidly, accurately and affordably measured. Similar to intake, these parameters must be measured without disrupting normal

grazing patterns. While eight-day vibracorders meet that criteria, their expense ($252 plus harness and chart costs), size, inability to be read without animal disturbance until data collection has ceased and the very objective and labor intensive way in which the charts must be read are serious disadvantages.

While vibracorders employ a vibrating pendulum to mark grazing time on wax-coated charts, more recent devices use mercury switches to activate recording devices (Pattinson et al 1981; Jones and Cowper 1975) whether they be mechanical or electrical. Two advantages of these devices is that with accumulated data remaining on the animal, the carrier must be caught to retrieve data or determine if the device is working. A second disadvantage is the inability to separate day and night grazing or grazing done at particular hours. One method of data gathering while not disturbing livestock is data sending by telemetry. Horn and Miller (1979) and Nichols (1966) attempted telemetry use in measuring intake and jaw movements, respectively. Neither of these two methods have had widespread use. The ARADS system (Adams, et al. 1987) uses telemetry and may have some application to intake measurement.

The objective at the Columbia, MO location was to build a grazing clock to overcome these deficiencies and which might be adaptable for measurement of additional grazing phenomena such as bite rate. A mercury switch located on the animal's halter was activated by the downward head position of the grazer if that position was held for a specified length of time. With that criteria being met, a telemetry radio signal was transmitted from the animal to an eight channel scanner in a building located about 300 yards distant which relayed data to a computer (Fig. 2) where it was massaged with custom software. The eight channel scanner can actually handle signals from 16 animals.

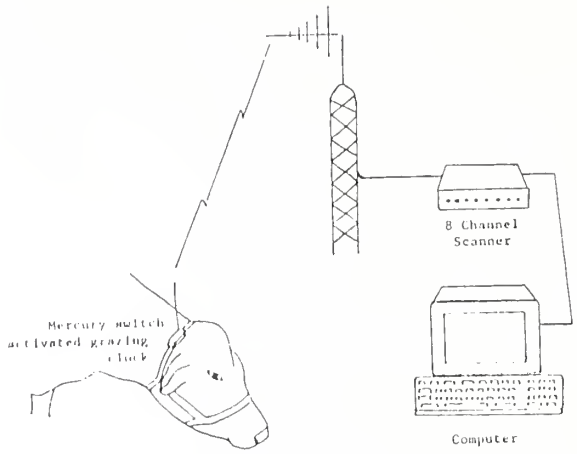


Fig. 2. Configuration of Telemetric Grazing Clock (TGC) data sending and receiving.

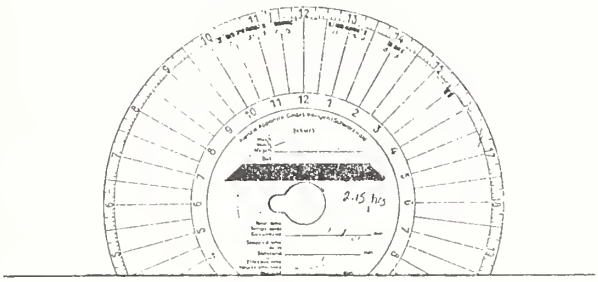
A comparison of vibracorder and telemetry data output is presented in Fig. 3.

Additional software is being prepared at present to allow greater data manipulation.

Two preliminary tests (one of four and one of seven hours) comparing vibracorder with telemetry data show the two devices to be very similar with the telemetry device perhaps resulting in slightly longer grazing times due to greater accuracy (data not shown). More extensive studies are underway at present. All of the electronics for this device are contained in a common metal household electrical receptacle which is bolted onto a nylon livestock halter. Present range of the signal is about 1.0 mile under current power (3.0 v). Accurate data can be collected out of line-of sight, but it is unknown at this point what geographical features might block the signal. Added battery power can increase signal strength, but is also larger, heavier and more expensive. It is anticipated that total cost per animal unit will be about $200.00. Since most locations have computers on-hand that may not be an additional expense. An antenna

and eight-channel scanner amount to about a $200 one-time investment. Total expense may be lowered by labor savings in vibracorder chart reading.

Although some advanced devices (such as a pressure transducer mounted in a tooth-borne partial denture which measured chewing; Kydd and Mullins, 1963) were constructed earlier, the last two decades have spawned numerous electronic devices



Start=22-13:46:43 *Stop=22 13:59:23 *Delta=760 *Sigma=7636
Start=22-13:59:43 *Stop=22 14:03:37 *Delta=243 *Sigma=7870
Start=22-14:03:52 *Stop=22 14:50:02 *Delta= 70 *Sigma=7940
Start=22-14:06:07 *Stop=22 14:32:59 *Delta=412 *Sigma=8352

Grazing Period Day & Start Time	Grazing Period Day & End Time	Time Spent Grazing This Period (Sec)	Total Time Spent Grazing (Sec)

Fig. 3. Partial grazing-time data formats for A) vibracorder and B) telemetric grazing clock.

and other means of measurement in grazing research. The list is likely to lengthen. However, it will be increasingly important to avoid duplication. Hopefully, the recognition that "this is not simply a question of encouraging collaborative work between plant and animal scientists where areas of interest conveniently overlap. It requires that the plant-animal interface itself be identified as the focal point for interdisciplinary research" (Horn and Hodgson, 1987) will speed the development of accurate and reliable means of gathering data needed to understand livestock performance.

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CAPACITANCE METER AND FALLING PLATE DISK METER METHODOLOGY AND USE IN GRAZING MANAGEMENT

J. Paul Mueller, J. T. Green and J. N. Rahmes

The need for rapid, accurate estimates of herbage mass[1] (HM) has long been recognized by researchers in pursuing a better understanding of sward-animal interactions and by advisors and farmers/graziers involved in the practical application of grazing principles.

Traditional methods of measuring HM in grazing studies have required samples cut from cages, strips or quadrats. Because pastures by nature tend to be variable with respect to HM, large sample numbers are usually required for HM estimates of satisfactory accuracy and precision.

In experiments involving rotational grazing, sampling is appropriate before and after a paddock is grazed, providing periods of stay are short (1-3 days). With set stocking or continuously grazed pastures, frequent sampling is necessary (at least bi-weekly) to assure adequate estimates of HM during the grazing period. The need to cut enough samples to ensure an accurate and precise estimate of HM would, in many cases, require a cadre of technicians on 24 hour duty to harvest and process samples. Also, the reductions in the amount of herbage on offer with destructive sampling could become unacceptable.

Naylor (1952) studied the influence of sample size and number on variation with the cage method of pasture sampling. He found that 51 cages per acre were needed to obtain a CV of 10% and that 13 cages per acre were necessary for a CV of 20%. Pastures were composed of orchardgrass-white clover and tall fescue-white clover mixtures (Dactylis glomerata L., Trifoluim repens L., Festuca arundinacea Schreb.) as well as grass dominated swards.

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[1]available forage, available pasture, pasture yield and forage on offer are considered synonymous with herbage mass.

Facing potentially prohibitive costs and the possibility that sampling may significantly alter HM, most researchers have reduced sample numbers to manageable levels based on available resources. This compromise often results in inadequate precision.

The expensive and cumbersome nature of destructive sampling has lead to widespread interest in non-destructive, indirect methods for estimating HM. These methods offer the potential benefits of speed, low labor input, and the ability to readily increase sample size and area resulting in improved precision. To be effective, all non-destructive methods must be strongly associated with HM in a manner that can be used to calibrate the method for prediction of HM. Methods include:

(1) Visual estimates
(2) Height measurement
(3) Height - density measurement
    (a) falling plate disk meter (FPM)
    (b) rising plate disk meter (RPM)
(4) Capacitance

Two of the most promising non-destructive methods involve instruments for measuring height - density and capacitance.

CAPACITANCE

A simple capacitor is composed of two parallel conductors (plates) separated by an insulator (dielectric). Capacitance refers to the ability of the capacitor to store electrical charge. Capacitance is determined by the nature of the dielectric material (dielectric constant), the surface area of the conducting plates and the distance between the plates.

Fletcher and Robinson (1956) were the first to report the application of capacitance measurements to in situ forage plants. They used two metal plates oriented vertically with respect to the ground and a combination of air and plant foliage as the dielectric material.

Campbell et al. (1962) made several improvements to the parallel plate type capacitor designed by Fletcher and Robinson, but concluded that too many deficiencies were present to warrant continued development. Instead, a multiple probe arrangement was developed using fifteen metal rods arranged in 5 rows of 3 rods each. Alternate rows were connected to form a two "plate" capacitor with a combination of air

and forage as the dielectric. The metal rods were inserted in plastic tubes to prevent direct contact with vegetation. This instrument could be inserted and removed from pasture swards with minimal disturbance. The researchers also made noteworthy improvements in the measurement of oscillator frequency.

Various refinements of the Campbell design were made by Hyde and Lawrence (1964), probe arrangement and solid state circuits; Johns and Watkins (1965), probe insulators, oscillator type and frequency; Jones and Haydock (1970), probe number and arrangement and Neal and Neal (1973), oscillator frequency drift, digital logic.

The next major advancement in capacitance meter design was the independent but simultaneous development of the earth-plate capacitance scheme by Nomoto (1975) and Angelone et al. (1980 a). This design was a departure from the multiprobe approach introduced by Campbell et al. (1962). The earth plate design employs air as the predominant dielectric of a two plate capacitor with the top plate of fixed area and the bottom plate of variable area. The area of the bottom plate is dependent on amount of plant material present which is considered an extension of the earth-plate. One of the apparent advantages of the earth-plate design over the multiprobe design is the way water is measured by the instrument. With the earth-plate approach, water takes the form of plant-water columns that appear as extrusions of the bottom (earth) plate rather than being a component of the dielectric between plates as in the multiprobe design. The earth-plate meter described by Angelone et al. (1980 a,b) although a significant advance in design, was cumbersome and employed a horizontal top (fixed) plate.

Vickery and Nicol (1982) introduced a streamlined earth-plate instrument by designing a single, vertically oriented probe which contained electronic components such as counting circuits, digital display and reset switch which attached directly to the probe top in a small box. Further refinement of this basic design by New Zealand scientists in collaboration with Design Electronics Ltd. of Palmerston North has resulted in the commercial production of the Pasture Probe ™ Mark III which is commercially available.

Several excellent reviews are available for those interested in the historical development of the capacitance probe: Neal and Neal (1973), Hyde and Lawrence (1964), Angelone et al. (1980a), and Richardson (1984).

The association between capacitance readings and HM has generally been reported to be high. Campbell et al. (1962) found highly significant linear relationship between meter readings and yield; CV's ranged from 5 to 27%. He cautioned against bias if pooled data were used in prediction. Over 90% of the variation in pasture yield (fresh or dry weight) was accounted for by the capacitance meter reading within a particular calibration series based on different pasture types. He cited day-to-day variation in sampling method precision, long, trampled pasture swards, and sensitivity to temperature and humidity shifts as significant sources of variability with the capacitance technique.

Contrary to early parallel plate and multiprobe capacitance meter findings, Toledo et al. (1980) reported that the earth-plate meter was more highly correlated with forage dry weight than fresh weight. He also reported relationship of meter readings to dry forage yield to be better for upright plant species (r^2=0.95-0.99) than for decumbent species (r^2=0.34-0.75).

Vickery and Nicol (1982) stated that the single probe earth-plate meter was responsive to foliage surface area and that even in pastures containing substantial quantities of dead material estimates of HM could be obtained with the meter. They reported a non-linear (Mitscherlich) response for a pooled data set. However, the response of individual tests was linear in most cases. It was stated that it is not necessary to cut, collect and dry samples for frequent recalibration of the instrument. Monthly calibration was suggested for most research studies and possibly a less precise general calibration for extension work. Using a probe constructed from the basic Vickery design, Roberts et al. (1984) studied the relationship between meter readings and HM of subterranean clover and ryegrass grown alone and in mixture. They reported different linear relationships for the different pasture types and emphasized the need for separate calibration equations.

Most HM estimation methods using a capacitance probe or disk meter have involved the computation of calibration regression equations. Researchers and advisors have from the beginning sought a general calibration relationship that would prove useful over a broad range of species and seasons (limiting the need for cutting samples). However, effects such as plant species, proportion of dead material, dry matter concentration, and proportion of bare ground have been found to influence probe calibration (Campbell et al. 1962; Johns and Watkins, 1965; Back, 1968; Jones and Haydock 1970; Johns, 1972; Toledo et al. 1980; Green et al. 1989).

Jones and Haydock (1970) used the mean capacitance meter reading (MR) based on many MR taken at random from a paddock to estimate HM without using regression calibrations. The method involved finding and cutting several quadrat samples within the paddock area having the same MR as the previously determined mean MR for the entire paddock. The HM determined from the cut samples was then averaged to estimate the HM from the entire paddock area. A modification to this method was suggested by Johns (1972) in which the HM from each cut quadrat was adjusted based on the relationship:

paddock HM = quadrat HM *
(mean Paddock MR/mean Quadrat MR)

This modification seems an improvement from the previous method because the time and difficulty in finding a quadrat with the same MR as the mean MR for the paddock are eliminated. Both of these methods assume that a linear relationship exists between HM and MR.

Falling Plate Disk Meter (FPM)

This instrument measures the compressed height of herbage beneath a disk which has been dropped from a pre-determined height along a calibrated central shaft and allowed to settle to a constant position. It is assumed that the level to which the disk settles on the shaft will directly reflect the HM of plants beneath the disk.

Sullivan et. al. (1956) used a method to estimate herbage height which involved dropping a 0.62 x 0.62m cardboard square onto the sward. Alexander et. al. (1962) reported a similar method that involved a 0.62 x 0.62m cardboard or plywood square which was used to estimate HM. The square was dropped from waist level onto the sward; the height from ground level to the midpoint of each of the four sides was averaged and herbage beneath the square was harvested for yield determination. The average height of the square was found to be closely related to HM for several pasture species (r^2=0.36-0.92). Phillips and Clark (1971) used a weighted-disk to study the relationship between disk height and HM. They used two mower types, reel and sickle-bar, and two disk weights to calibrate disk readings to HM. Visual estimates of yield were also made. The authors found high correlations between HM and meter readings (r^2 = 0.50-0.98) but a marked shift in slope (b) was noted from spring to winter. It was concluded that the disk meter was capable of detecting small differences in pasture growth and that it was superior to a skilled technician in estimating HM.

Herbage mass was estimated by Powell (1974) on intensively grazed dairy pastures with the weighted disk meter described by Phillips and Clarke (1971). He found the best relationship between the meter and HM to occur in winter and the worst in summer and autumn. The accuracy of the meter as a predictor of HM was acceptable in winter but not in summer and autumn (r^2 = 0.78-0.92 and 0.02-0.58 respectively).

Castle (1976) found linear regressions of HM on disk height explained 80-90% of the variation in clipping experiments and 39-62% in grazing experiments. Different slopes (b) were reported for different seasons (spring, summer, fall) and plant species. Errors were relatively high, but because the falling disk meter was simple to operate, inexpensive to build and fast to use, the author concluded that it may be useful in research and in general grassland management.

Bransby et. al. (1977) studied the influence of four different disk sizes and weights on the association of disk height and HM on tall fescue pastures. Neither size nor weight had any significant effect on RSD or r. Changes in b were evident as plants progressed from vegetative to reproductive growth. Values for r^2 ranged from 0.62 to 0.88.

The sampling technique of Jones and Haycock (1970) was employed by Vartha and Matches (1977) in an attempt to maintain experimental precision when cutting a low number of samples for estimation of HM in a grazing experiment with tall fescue. Season was found to influence the proportion of variation explained by regression; r^2 = 0.51, 0.68 and 0.50 for spring, summer and fall respectively. The grazing

management treatment also influenced r^2 values. Trampling of herbage and the accumulation of mature growth were cited as factors responsible for reductions in r^2 values.

Rising Plate Meter (RPM)

The RPM (also called the Massey Grass Meter or Ellenbank Pasture Meter) is designed such that a $0.1m^2$ plate is forced up a calibrated rod to a height dependant on the HM present beneath the plate (height in cm is read by a counter). This corresponds in most respects to the "settled height" of the falling plate disk meter (FPM) previously described; the difference being that with the FPM the disk is dropped from above the sward in contrast to being forced up from the sward surface by the herbage. The RPM is semi-automated in that a counter records the cumulative height and the number of measurements so that a simple division can be made to obtain the average reading for a large number of samples.

Stockdale (1984) used the RPM to estimate HM from intensively grazed, irrigated dairy pastures. He found HM of pre-grazed pastures was measured more precisely than HM of post-grazed pastures. Factors such as botanical composition, season, herbage dry matter concentration, and lodging and trampling of herbage were cited as influencing regressions. Lodging and trampling effects were judged to be most detrimental to precise estimations of HM. He speculated that the single probe capacitance meter may provide a better estimation of HM from trampled pasture than the RPM. Stockdale and Kelly (1984) later reported in a comparison between RPM and the single probe capacitance meter on intensively grazed dairy pastures that neither instrument performed satisfactorily where uneven trampling and lodging of the herbage was present. They suggested that pooled regressions were unsuitable for research purposes unless pooling was for a short period.

L'Huillier and Thompson (1988) estimated HM in swards of white clover - perennial ryegrass (Trifoluim repens L. - Loluim perenne L.) using a single probe capacitance meter (Pasture Probe™), the rising plate meter (RPM), sward height and visual assessment. They found the Pasture Probe™ and calibrated visual assessment to be slightly more accurate than other methods, however, without calibration, visual assessment was the least accurate method.

The researchers suggested that pooling calibrations from various locations could result in the derivation of "universal" calibrations for the estimation of HM.

SUMMARY

We have been working with nondestructive estimation of HM since 1986 on clipped swards and in grazed pastures to help quantify grazing management treatments. HM estimates were made with the Pasture Probe ™ (capacitance meter) and a falling plate disk meter (FPM) as described by Vartha and Matches (1977). Our FPM was constructed with some modification from the previous design: the disk was a 0.2 m circular sheet of clear, Lexan plastic; a 112 cm long tubular aluminum collar (i.d. 22 mm) was attached to the disk, the weight of the disk plus collar was 1.21 kg; a solid aluminum rod, 1.97 m long, 19 mm diameter, calibrated in 1-cm intervals from 0 to 85 cm was used as the central shaft.

In addition to the probe and the FPM we have used (to a lesser extent) a semiautomatic rising plate meter described previously. We have found all of these instruments, in certain situations, to be useful in estimating HM from cut plots and grazed pastures. Rough estimates of animal intake are also possible with controlled, rotational grazing management as long as the grazing period is short (1-3 days) and stocking density is sufficient to ensure uniform grazing.

Both the Probe and the FPM gave similar overall estimates of HM as evidenced by the statistics presented in Table 1. However, the ability to precisely characterize sward canopies may be necessary to obtain the best estimate of HM. In a study on tall fescue pasture using the FPM to estimate HM, we found that the regression equation for vegetative canopies was very different from the one derived from canopies of reproductive tillers (Table 1). Furthermore, relatively open canopies with appreciable bare ground produced different regressions than more dense canopies with little bare ground (Table 1).

Multiple regression may result in improved equations if the variables can be easily quantified. When FPM readings and visual estimate of bare ground were included in a multiple regression, the variation explained by the model and the RSD were greatly improved. The addition of the bare ground estimate increased the proportion of the variation explained by regression from 85 to 93 percent and reduced RSD from 651 to 444 kg ha^{-1}.

Table 1.The relationship between capacitance meter (Pasture Probe™) and falling plate disk meter readings and the prediction of herbage mass from cut swards of tall fescue, 1987.

ITEM	n	r^2	RSD	SLOPE (b)	INTERCEPT (a)
OVERALL					
Probe	44	.90	536	26.1	-431.6
FPM	48	.85	651	185.4	1488.1
CANOPY TYPE (FPM)					
Vegetative	40	.76	456	474	-483
Reproductive	8	.73	454	120	3148
BARE GROUND % (FPM)					
<23	29	.87	588	161	2100
>23	19	.24	398	219	860

n = number of observations or means in the regression.
r^2 = coefficient of determination (simple linear regression).
RSD = Residual standard deviation.
FPM = Falling Plate Disk meter.

Even though the "pooled" equations appear to be fairly good, lack of precision in the estimation of individual values limits the usefulness of such 'overall' or 'universal' regressions. It appears that accurate estimates of HM will require cutting a limited number of samples every time an estimate is desired. Since our experience and the evidence in the literature supports the existance of a linear relationship between HM and meter readings, the noncalibration method suggested by Johns (1972) seems to be the best approach to obtaining a reasonably accurate estimate of HM with minimal resources.

It is understandable that scientists, advisors, and farmers desire a simple "universal" predictor of HM that will not require the cutting of quadrats. Nevertheless, we conclude that it is unlikely that researchers will be able to develop "universal" prediction equations that will be widely applicable and offer the accuracy required. Accurate estimates of HM will require that some minimal amount of quadrat sampling be done for each day and for each pasture type for which estimates are desired, however, less accurate estimates may be satisfactory for on farm feed budgeting or certain areas of grazing research. Perhaps as data accumulate for specific seasons, environmental conditions, pasture types and grazing managements, individual prediction equations will be capable of precise and accurate HM estimates without sample cutting.

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ESTIMATING INTAKE USING RARE EARTH MARKERS AND CONTROLLED RELEASE DEVICES

K. R. Pond, J. M. Luginbuhl, J. C. Burns, D. S. Fisher and S. Buntinx

INTRODUCTION

Prediction of voluntary intake of forage by grazing ruminants requires estimation of the quality of the forage consumed (digestibility) and of the fecal output by the animal. Voluntary intake (VI) can then be calculated:

$$VI, g/d = \frac{\text{dry matter fecal output, g/d}}{1 - (\text{digestibility}/100)}$$

Samples of selected forage can be readily obtained using an animal fitted with an esophageal cannula. Plucking samples by hand is an alternative where surgically modified animals are not available. The digestibility of the animal's diet can then be estimated either by an in vitro analysis (Burns and Cope, 1974) or by using an internal marker (Cochran et al., 1987). Forage yield samples or whole plant cuttings would not likely represent the quality of the diet selected by the animal.

Cooperative investigation of the USDA-ARS, The Small Ruminant Collaborative Research Support Program and the North Carolina ARS, Raleigh, NC. Paper No. 12300 of the Journal Series of the North Carolina ARS, Raleigh, NC 27695-7643. Use of trade names in this publication does not imply endorsement by the North Carolina ARS or by USDA-ARS nor criticism of similar products not mentioned. Assoc. Prof. Anim. Sci.; Research Assoc. Anim. Sci.; Plant Physiologist, USDA-ARS and Prof. Crop and Anim. Sci.; Plant Physiologist, USDA-ARS and Assist. Prof. Crop Sci.; Graduate Student Anim. Sci.; North Carolina State University, Raleigh, NC 27695-7621.

Estimates of fecal output are more difficult to obtain than estimates of digestibility. An animal's total fecal output can be collected with a fecal bag and collection harness. However, this is laborious and unsatisfactory for most grazing studies (especially during the spring when forage quality is high or in rugged terrain). Alternatively, fecal output can be computed without total collection by using indigestible markers. The purpose of this paper is to review and describe procedures of two accepted marker methods and to report results of a new method using a controlled release device.

AVAILABLE MARKERS AND DESCRIPTION OF MARKER METHODS

Two accepted marker methods for estimating fecal output are: 1) single (pulse) dose administration followed by frequent sampling to obtain the saturation-desaturation fecal marker appearance curve, and 2) daily marker administration to generate a steady state marker appearance in the feces.

A new controlled release device marker to method has been developed and is now commercially available. Each method will be described in detail and results from using the new controlled release device will be presented.

Markers traditionally used for fecal output determination have been various rare earth elements (REE) and chromium (Cr). The use and analysis of REE and Cr for passage and fecal output estimates have been described elsewhere (Pond et al., 1989 and Pond et al., 1985). Chromic oxide (Schneider and Flatt, 1975) and Cr mordanted to fiber (Uden et al., 1980) have been widely used because they are economical, and the concentration of Cr can be determined by a number of methods. The new controlled release device utilizes chromic oxide as the marker. Of the REE, Ytterbium (Yb), Dysprosium (Dy) and Erbium (Er) have been most popular because they are sensitive to analysis via atomic absorption spectrophotometry. Many other REE can be used if neutron activation analysis or plasma emission spectroscopy are used for detection. If the main objective of an experiment is to

use markers for fecal output determination, then the choice of marker is not critical. However, if rate of passage, rumen fill, or retention time are to be estimated, the marker must have movement characteristics similar to the grazed forage.

Single (Pulse) Dose Method

The single (pulse) dose method estimates output of feces by determining from change in marker concentration over time following a single administration of the marker (Figure 1). After a time delay between administration and first appearance in the feces, the concentration of the marker in the feces increases to a peak and then decreases to below detectable limits. A major disadvantage of this method is the need for the numerous fecal collections required for constructing the curve in Figure 1. Several one- and two-compartment models have been developed to describe the marker appearance curve (Pond et al., 1988). In most grazing studies the one-compartment model with time delay and gamma two age dependency has given the best fit. The model is:

$$y = (k_0 L_1 (t-tau) e^{-(L1(t-tau))}/0.59635$$

Where y = concentration of marker,

k_0 = concentration of marker if instantaneously mixed in the compartment,

L_1 = age dependent rate parameter

tau = time delay

t = time after marker administration

Output of feces (FO) is then computed as:

$$FO, g/d = \frac{\text{Marker dosed, ug}}{k_0, \text{ ug/g}} \; x_L * 24 * 0.59635$$

In addition to fecal output, the single dose method also provides information on the rate of passage and mean retention time of digesta in the digestive tract and the fill of undigested residues:

$$\text{Rate of passage, } h^{-1} = L_1 * .59635$$
$$\text{Mean retention time, } h = (2/L_1) + tau$$

$$Fill, g = \frac{\text{Marker administered, ug}}{k_0, \text{ ug/g}}$$

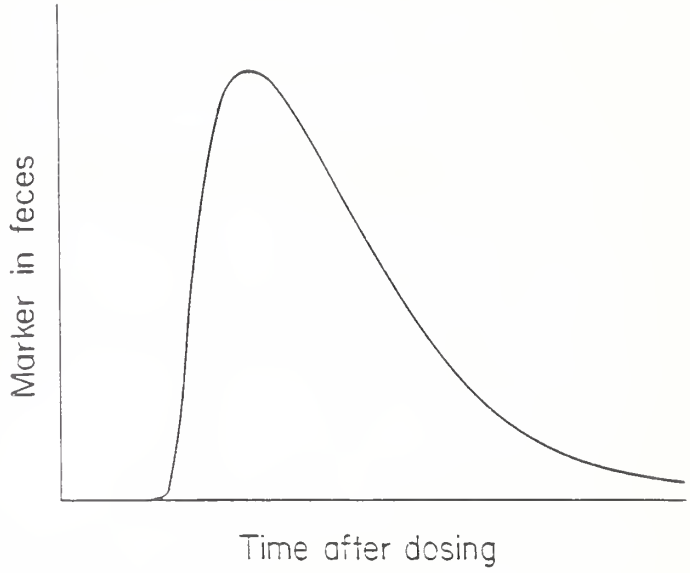

Figure 1. Concentration of marker in the feces after administration.

The single dose marker method is the technique that we have found to be most workable and reliable. We use both a liquid marker (cobalt-EDTA) and a particle marker (chromium mordanted or rare earth labeled fiber) in most of our trials. Typically, animals are dosed at 0600-0700 h and samples of feces obtained from each animal at 5, 9, 13, 17, 24, 28, 31, 35, 38, 41, 48, 55, 61, 72, 79, 85, 97 and 109 h postdosing. Samples are obtained by following animals until they defecate and spooning the feces into prelabeled plastic bags, or by moving animals to a squeeze chute for rectal grab sampling. Two of the sampling periods (h 17 and 41) occur at 2300 h (after dark). The use of flashlights and miners' head lamps facilitates nighttime sampling.

The cobalt, chromium or rare earth in the feces are extracted with acid (Quiroz, et al., 1988) and assayed by atomic absorption spectrophotometry. Once the concentrations of marker in the feces are determined, they are fitted to the one compartment model with time delay and gamma two age dependency as listed above. As an example; the data file for animal number 86-19 are presented in Table 1 with columns for time of collection post dose and concentration of chromium. The SAS program for fitting the collected data to the model is presented in Table 2.

The actual and predicted fecal excretion curves are presented in Figure 2. The predicted and actual concentrations of the marker in the feces are very similar. This type of plot is part of the program in Table 2.

Table 1. Fecal chromium data for animal 86-19

Hours post dose	Chromium Concentration (ug/g)
5	0
9	0
13	.6
17	37
24	70
28	78
31	80
35	76
41	61
48	50
55	39
61	28
72	18
79	11
85	6
97	2
109	0

Table 2. The program for fitting fecal marker concentration to a one compartment model with time delay and gamma two age dependency utilizing SAS (1985).

```
DATA GRAZE1; INFILE GRAZE;

INPUT ANIMAL TIME CR;
Y=CR;
PROC SORT; BY ANIMAL;
PROC NLIN ITER = 50 CONVERGENCE = .00001
  METHOD = MARQUARDT; BY ANIMAL;
PARMS KO = 100, L1 = .05, TAU = 10;
BOUNDS KO>0, L1>0, TAU>0;
T = TIME - TAU;
IF T>0 THEN GO TO ALPHA;
E1 = EXP (-L1 *T);
ONE = T*(L1**2)(*E1);
MODEL Y=((KO*L1*t)*(EXP(-L1t)))/.59635;
  DER. KO = ONE;
  DER. L1 = T*L1*KO*E1*(2-L1*T);
  DER. TAU = KO*(L1**2)*e1*(L1*t = 1.0);
GO TO BETA;
ALPHA;
  MODEL Y = 0;
    DER. KO = 0;
    DER. L1 = 0;
BETA:;
OUTPUT OUT = POINTS1 PREDICTED = YHAT
  RESIDUAL = RESID;
DATA OK; MERGE POINTS1 GRAZE1;
PROC SORT; BY ANIMAL;
PROC PLOT; BY ANIMAL;
  PLOT YHAT *TIME = * Y*TIME = +
  /OVERLAY; LABEL TIME = TIME AFTER
  DOSE, HOURS;
```

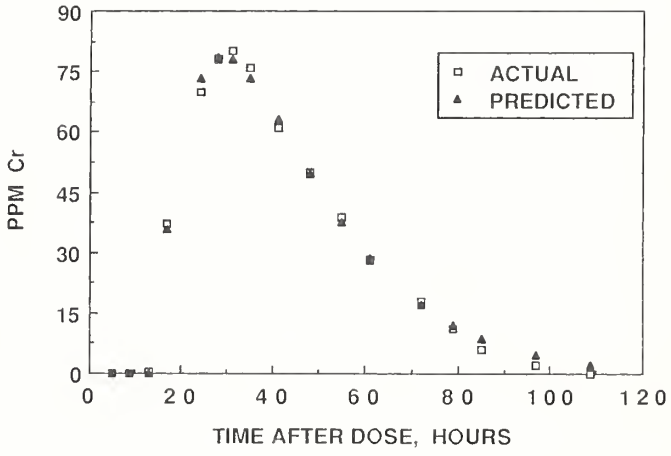

Figure 2. Actual and predicted fecal Cr excretion curves.

The predicted parameters from the model were:

K_0 = 127.449
L_1 = .0672
tau = 13.929

The dose of chromium mordanted fiber given to this steer was 347170 ug. The computations of interest are:

1) Rate of passage
   = .0672*(.59635) = .0401 h^{-1}
2) Mean retention
   time = (2/.0672)+13.929 = 43.69
3) Fill of undigested dry
   matter = 347170/127.449=2723.99 g
4) Fecal
   output = 2723.99(.0401)(24)
   = 2621.56 g/d

The quality of the animal's diet was estimated from esophageal collections made in plastic bags (saliva retained) at dawn during the animal's normal grazing period. The extrusa was flattened, quick frozen in liquid nitrogen and stored in a freezer until freeze dried and ground to pass through a 1-mm screen prior to quality determination. Digestibility was estimated from in vitro dry matter disappearance (Burns and Cope, 1974). The in vitro digestibility of the diet of this steer was 74.1%. The daily voluntary intake (VI) of dry matter of the steer was estimated:

$$VI = \frac{2621.56\ g/d}{1-(74.1/100)} = 10{,}121.85\ g/d$$

Daily Marker Administration Method

In this method, daily administration of a known quantity of a marker is followed by periodic sampling of feces. The concentration of the marker in the feces is then determined. To obtain equilibrium (steady state conditions) the marker must be administered for at least five days prior to sampling. Grab samples of feces should be collected over 3- to 7-days to obtain a mean marker concentration. Diurnal variation has been reported for several markers so multiple sampling times are recommended. Fecal output (FO) is then calculated as follows:

$$FO,\ g/d = \frac{\text{marker administrated, ug/d}}{\text{marker concentration in feces, ug/g}}$$

Daily administration of a marker in trials that involve supplementation with grain is easily accomplished. Chelates of rare earths, chromium and cobalt can be added to the supplement in liquid form. After the mixture has dried, individual allowances can be weighed out to be fed once or twice daily. Animals must be individually fed and all of the marker must be consumed. Fecal output is then estimated from the mean of representative fecal samples. Because most grazing studies do not involve grain supplementation and do not utilize individual feeding stalls, the marker must be administered daily to the animal by dosing.

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Chromic Oxide (Cr_2O_3) powder is often administered to animals in gelatin capsules either once or twice daily. Chromic oxide impregnated paper has also been successfully used but is no longer commercially available. Also, dried marked fiber (sometimes using rice hulls as a carrier) can be dosed daily with a balling gun. Alternatively, liquid markers can be administered orally with a syringe. Under range conditions, others have injected a solution of Yb into the rumen with a syringe and large needle by penetrating the skin and muscle at the paralumbar fosa. The daily marker administration procedure has the disadvantages of a daily labor requirement for marker administration, the possible injury to animals during administration and problems in maintaining consistent daily marker intake. However, an advantage is the simple mathematic treatment of the data.

Continuous marker infusion

Infusion pumps for administering markers have also been developed and utilized. Ellis (1978) developed a portable infusion pump to deliver a set amount of marker solution at prescribed times. The pump fits inside the lid of a ruminal cannula. Commercially available portable peristaltic pumps that attach to the back of the animal and administer markers directly into the rumen are available (Siropump, Everest Electronics, 61 Compass Drive, Seaford, South Australia). The pump also can be set up to sample ruminal fluid or saliva. Ulyatt et al. (1988) have utilized another type of infusion pump for grazing animals. Use of pumps to administer markers reduces diurnal variation and reduces stress on the animal.

Evaluation of the Controlled Release Device

A controlled release chromium sesquioxide (Cr_2O_3) capsule developed recently in Australia by Captec for commercial use in cattle and sheep (Ellis et al., 1987) is the fecal output of animals. Each capsule consists of a plastic outer barrel and wings, a stack of tablets containing the fecal marker Cr_2O_3, a spring and a plunger. The wings are folded and held in place during dosing by a water soluble tape. On contact with ruminal fluid the wings unfold to decrease the probability of regurgitating the capsule. The release of Cr_2O_3 starts when water passes through the enc of the capsule and is absorbed by the first tablet. The tablets contain water soluble compounds which form a gel when in contact with moisture. The gel containing Cr_2O_3 is slowly extruded through the end of the capsule by the spring-loaded plunger. When steady state is achieved (4 to 6 days after dosing), the mass of Cr_2O_3 released by the capsule is equal to that appearing in the feces. Fecal samples may be collected between days 6 and 20 in cattle and days 5 to 25 in sheep. In vivo performance tests are conducted by Captec on each batch of capsules produced to assess the Cr release rate. Therefore, FO can be predicted by simply determining Cr concentration in the feces as noted below:

$$FO = \frac{\text{Cr release rate, mg/d}}{\text{concentration in feces, mg/g}}$$

Capsules should be dosed with caution and into the back of the oral cavity to assure swallowing rather than inhalation and probable death by suffocation. During deglutition, the transit of a capsule down the esophagus can be followed visually. The water soluble wing tape dissolves within five minutes after contact with sufficient saliva or ruminal fluid. Incomplete deglutition and regurgitation of a capsule have occurred. Therefore, dosed animals should be kept in an individual enclosure for approximately 10 minutes. The capsules should be marked to facilitate redosing any animal regurgitating its capsule.

The controlled release device has the advantage of one time dosing and allows flexibility in time for sampling. To provide reasonable estimates of fecal output, the rate of Cr_2O^3 release must be constant and not affected by diet, animal or level of intake. Critical evaluation of the capsules are not available in the literature.

The reliability of the Captec capsule was evaluated by: 1) determination of the rate of Cr_2O_3 release as affected by diet and intake level, and 2) comparison of actual FO and

predicted FO with animals fed a wide range of diets. In the first trial eight ruminally-cannulated steers fed either alfalfa hay or Coastal bermudagrass hay ad libitum, or fed a pelleted commercial sheep diet at 2.5% or 1.5% of body weight (BW), were dosed orally with a Captec capsule. The capsules were recovered from the rumen and the remaining chromium measured every three days until all the chromium was released. Release rate of chromium was determined by regressing chromium remaining with time.

Release of Cr_2O_3 from the capsules was complete after 17 to 20 days in steers fed alfalfa hay, after 20 to 23 days in steers fed the pelleted diet at 2.5% BW and after 23 to 26 days in steers fed either Coastal bermudagrass hay or the pelleted diet at 1.5% BW (Figure 3). Neither diet ($P<.3$) nor level of intake ($P<.2$) had an effect on Cr_2O_3 release rate (Table 3). However, some trends were present that may warrant further investigations.

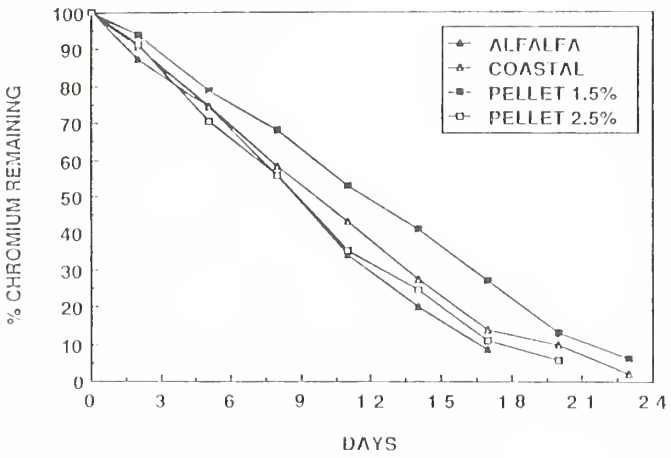

Figure 3. Chromic oxide release rates from capsules dosed to steers fed four diets (1 capsule/steer).

Table 3. Release rate of Cr#03 from captec capsules and intercepts of regression lines.

Diet	Release rate %	Intercept of regression line
Alfalfa hay	5.81	100.60
Coastal bermuda-grass hay	5.04	99.57
Commercial sheep pellets, 1.5% BWa	4.24	100.6
Commercial sheep pellets, 2.5% BW	5.35	99.17
SE	.511	8.58

aBW = body weight.

Unfortunately, differences in Cr_2O_3 release rate were observed among an#mals fed the same diet (Figure 4). These differences could not be attributed to either an animal or capsule effect because each animal received only one capsule.

A second trial was designed and conducted with nine ruminally-cannulated steers fed three of the four diets used in trial 1. Steers were each individually dosed with four Captec capsules. Chromic oxide was completely extruded 18 to 21 days following dosing in steers fed alfalfa hay and six days later in steers fed either level of pelleted feed (Figure 5).

Release rate of Cr_2O_3 was higher for alfalfa hay (4.94%; $P<.01$) compared to both levels of pellets, which were similar (2.5% BW: 4.47%; 1.5% BW: 4.21%; $P<.4$). Intercepts of the regression lines were similar among diets (avg: 101.97). However, rates of Cr_2O_3 release differed among animals fed the same diet ($P<.01$). The difference between minimum and maximum release rate among animals fed the pelleted diets (range: 1.5% BW, .69%; 2.5% BW, .58%) compared to animals fed alfalfa hay (range: .29%) accounted for most of these differences (Figures 6, 7). Release rate of Cr_2O_3 among capsules dosed to the same animal generally differed little (Figures 8 and 9).

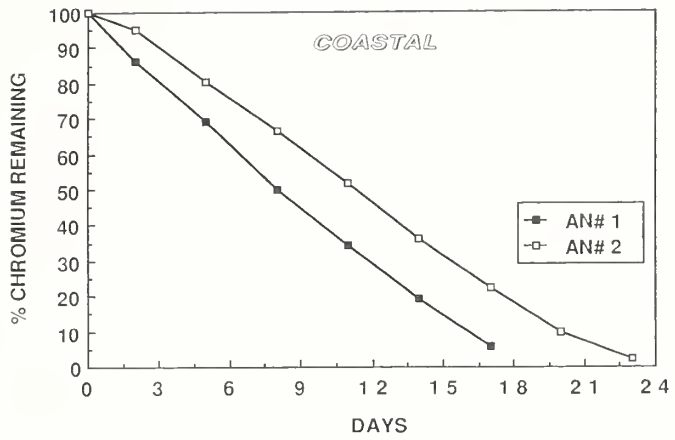

Figure 4. Chromic oxide release rates from capsules dosed to two steers fed the same diet (1 capsule/steer).

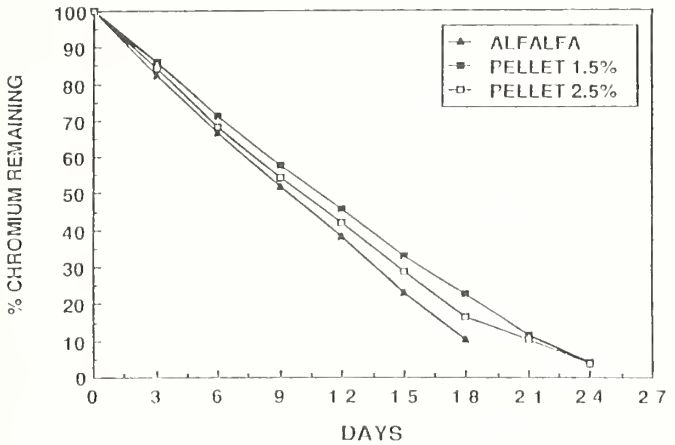

Figure 5. Chromic oxide release rates from capsules dosed to steers fed three diets (4 capsules/steer).

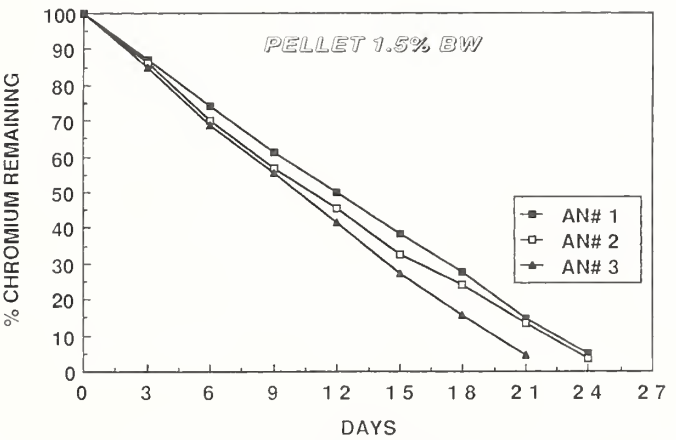

Figure 6. Chromic oxide release rates from capsules dosed to three steers fed a pelleted diet at 1.5% BW (4 capsules/steer).

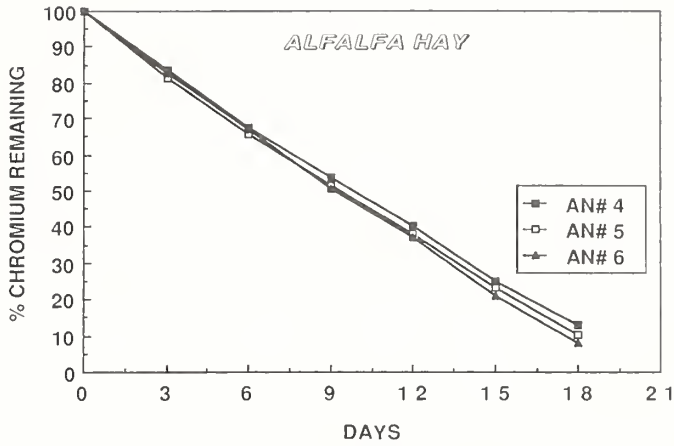

Figure 7. Chromic oxide release rates from capsules dosed to three steers fed alfalfa hay (4 capsules/steer).

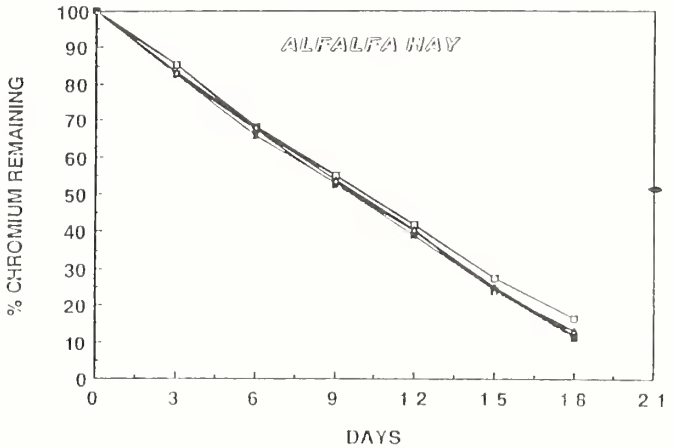

Figure 8. Chromic oxide release rates from four capsules dosed to a steer fed alfalfa hay.

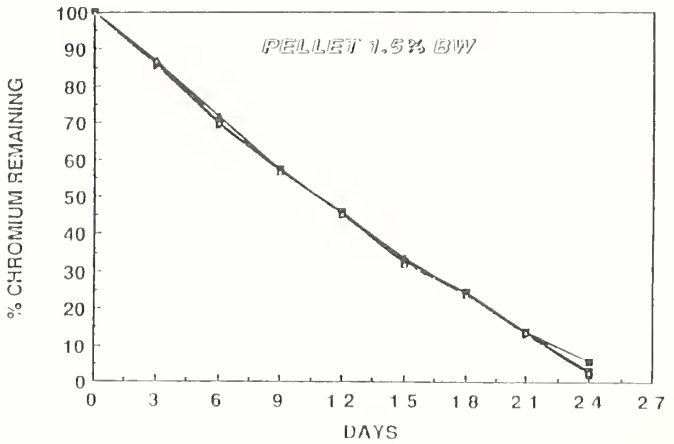

Figure 9. Chromic oxide release rates from four capsules dosed to a steer fed a pelleted diet at 1.5% BW.

In a third trial, daily output of feces by total collection was compared to predicted daily output estimated by dosing 24 pen-fed wether sheep with Captec capsules. Results using data from days 8 to 17 (Figure 10) or 5 of the 10 days chosen at random (Figure 11) showed good agreement between actual and predicted fecal output. The slightly greater variation observed when choosing 5 days at random compared to using 10 consecutive days of data is to be expected.

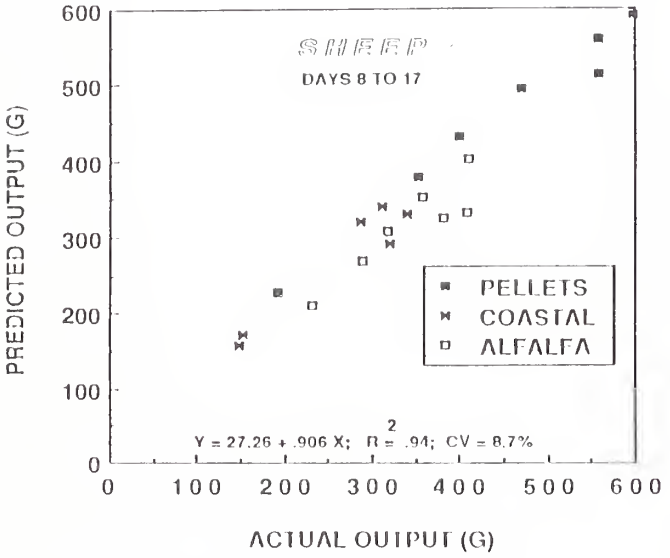

Figure 10. Comparison of actual versus predicted daily fecal output in sheep (data from days 8 to 17).

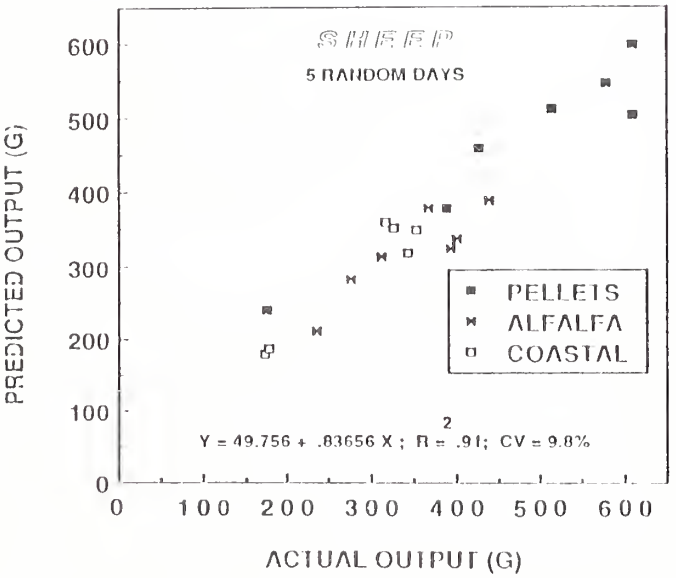

Figure 11. Comparison of actual versus predicted daily fecal output in sheep (data from 5 random days).

Evaluation of the intraruminal controlled release fecal marker capsules demonstrated that they can be used to estimate fecal output and therefore voluntary intake. On-going research at NCSU involves testing Captec capsules with grazing sheep and cattle. If the capsules perform satisfactorily, use in grazing studies could allow major savings in labor compared to the frequent dosing or sampling associated with daily administration or with the pulse dose marker techniques.

Conclusions

Marker methods are available for estimating fecal output of grazing animals. If the quality of the diet is known, the estimation of voluntary intake is possible. Of the three methods discussed the single dose method, although requiring more sampling time (some at night), has the advantage that rate of passage, mean retention time and fill of undigested residues can also be computed from the data. The daily dose method or use of an infusion pump has the advantage of fewer sampling times, and easy mathematical treatment of the data, but marker administered must be constant and only fecal output can be computed. The controlled release device looks very promising but differences in release rate of Cr due to animal or diet can increase errors associated with fecal output estimation. More detailed evaluations need to be conducted before its use can be recommended in research projects.

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GRAZING RESEARCH: EXPERIENCE AND PHILOSOPHY

Marvin E. Riewe

When Dr. Tharel asked me to appear on your program this morning, I indicated to him that I thought it probably would be difficult to improve or add to the papers presented by Drs. A. G. Matches, D. I. Bransby, and W. J. Drane at the 1988 General Program for SPFCIC in Lexington, KY.

Dr. Tharel's invitation was probably prompted because of my involvement, along with many others, in a symposium at the 1988 Crop Science Society of America annual meeting in Anaheim, CA, entitled "Grazing Research: Design, Methodology and Analysis," with a subsequent CSSA/ASA special publication of the same title with a scheduled publication date of August 1989. Ten papers were presented at the November 1988 symposium and are included in the special publication. These papers were written by some twenty authors and co-authors.

OBJECTIVES OF GRAZING TRIALS

Grazing experiments with livestock are required to define input-output relationships that cannot be provided by laboratory, greenhouse, or field plot studies. In the design of grazing experiments, inputs, considered treatments, may include (1) new cultivars or species, (2) quality improvement such as increasing the contribution of legumes to pasture, (3) alternative methods of sward management, (4) using several animal pressures to understand better the many factors associated with pasture utilization, and (5) other alternatives or combinations. Outputs include animal, plant, and/or economic responses.

Input variables are numerous and some of them interact strongly. The level of some input variables may importantly condition the output of other input variables; e.g., the output of a grazing system conditioned by level of stocking or available forage. To study experimentally all input variables in a joint way (by factorial experiments with each variable at several levels) is, of course, not feasible. Therefore, a researcher must make judgements on what the most important inputs are, nutritionally and economically, and the ranges over which they should be studied. He must also make judgements about which interactions are important (nutritionally and economically) and which are not.

Few, if any, researchers have sufficient resources to study more than one or two factors at a time and have each factor at several levels. Thus, a conceptual framework and an associated technique for integrating the results from different experiments are needed. The conceptual framework dictates in large part how individual experiments are to be conducted and analyzed and the sequence in which experiments are to be conducted.

Almost without exception, grazing experiments constitute mission-oriented research and should be expected to produce results that are relevant, directly or indirectly, to the producer. Much grazing research is compartmentalized to the extent that practical relevance depends on the usually intuitive integration by the producer of the new information into livestock/pasture systems (Brougham 1981). The success of the experimental program is then determined by whether or not a producer can optimize significantly more precisely when experimental results become available than he was able to do before.

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NON-RANDOM VARIABLES

The CSSA special publication includes three papers on design of grazing experiments (Bransby 1989; Drane 1989; and Giesbrecht 1989). Nevertheless, it seems appropiate here to call special attention to the problem of non-random variables in grazing trials (Lucas 1964).

Randomization assumes that when variables under study are assigned in a random manner, the effect of non-random variables not under study follow anormal distribution. Non-random variables may, however, interact significantly with variables under study. The failure to properly take into account the effect of site, year, stocking rate or level of forage available (height or kg ha^{-1}), and supplemental feed are but a few examples encountered in grazing trials. Much "apparent" randomness in grazing trials has not been a true random effect at all but rather that of an unidentified non-random effect; e.g., the interaction between grazing system and levels of stocking rate or available forage.

It has been postulated that 1200 to 1600 kg ha^{-1} or 4 to 6 kg 100 kg animal liveweight day^{-1} of forage needs to be available so that the grazing animal (bovine) may attain maximum consumption (Mott 1980). It was further postulated that this should enable the investigator to use only one but variable stocking rate, which presumably can be estimated to be near the optimum production. This seems to ignore pervasive evidence that there may be a significant interaction of stocking rate or level of available forage (height or kg ha^{-1}) with grazing system (McIlvain and Savage 1951; McMeekan and Walsh 1963; Riewe 1965; Hull et al. 1967; and Blaser et al. 1969), with grass species or cultivars (Riewe et al. 1963 and Conrad et al. 1981), and with species combination (Jones and Sandland 1974). These interactions are biologically and economically important and if ignored may render the results of the grazing trial of little value. If a significant interaction exists between variables, there is little further interest in the mean of the respective variables.

The assumption that the stocking rate or level of acceptable forage (height or kg ha^{-1}) that provides for near maximum gain $animal^{-1}$ also provides for near maximum animal liveweight gain ha^{-1}, and thus is the "optimum stocking rate", is difficult to substantiate. The difficulty with this assumption is that the stocking rate allowing for maximum liveweight gain ha^{-1} appears to be at least double and perhaps up to triple that allowing near maximum liveweight gain $animal^{-1}$ (Riewe 1963; Jones and Sandland 1974; Conrad et al. 1981). The "optimum stocking rate" has been ill defined in studies where animals are grazed to maintain a single pre-determined level of available forage expressed as height or kg ha^{-1}.

PASTURE SYSTEM COMPONENTS

Components of pasture systems are generally evaluated "individually" in conventional grazing trials. Conventional grazing trials only infrequently evaluate whole pasture systems (Matches 1981). Conventional grazing trials are rarely satisfying in that they do not usually provide sufficient data to explain differences in the performance of animals grazing several kinds of pasture or managed in several different grazing systems (Forbes 1988). Because of the scale of the grazing trials, the limited number of sward measurements may not provide an adequate description of the pasture nor always allow an adequate number of observations to be made on the animals. Thus, some investigators have developed techniques that use small-scale and short duration trials to provide considerable control of sward conditions and animal responses.

Coleman et al. (1989) have made the case that with the complexity of the soil-plant-animal (SPA) relationships, a diversity of inputs may yield similar output because of compensation by certain components of the system. Thus, progress in understanding the interactions occurring at the plant-animal interface has been slow. These authors suggested that if the dynamic nature of the SPA complex is considered and short term

changes are monitored frequently, then the data can potentially be extrapolated to other situations.

DYNAMIC SIMULATION MODELS

Data gathered in small-scale short duration trials are potentially useful in developing an understanding of complex interactions between forages and animals at the plant-animal interface. Because of the restrictions imposed in such trials, it is also obvious that conclusions may be drawn that are somewhat removed from the "real world". Nevertheless, such trials can provide data that, when used with care, are useful in developing useful dynamic simulation models.

Plant and animal scientists conducting grazing trials rarely develop simulation models. Scientists (modelers) that develop simulation models rarely conduct grazing trials (Loewer 1989). Data gathered in small-scale short duration trials almost certainly require integration into some sort of model, either statistical, mechanistic or simulation, for the data collected to be an aid in developing economically useful pasture systems. Therefore, the plant and animal scientist usually require the service of a modeler to integrate the new information into a dynamic simulation model useful in providing useful mathematical logical expressions that relate inputs and outputs. Likewise, the modeler requires the help of plant and animal scientist in developing simulation models that really do simulate something in the "real world."

The usefulness of a simulation model lies in its ability to predict "real world" happenings. This cannot be reasonably assured without thorough validation. It is almost impossible to validate too much. A simulation model, after years of development and validation, may still absurdly predict that "70% of two-year old heifers nursing a first calf will breed when fed a ration consisting only of 45% digestible hay." After all, mathematical modelling is a human activity (M. E. Riewe, unpublished).

Validation of outputs of pasture systems projected via simulation models requires a substantial experience data base from grazing trials, either previously conducted or yet to be conducted.

It is during the validation process that the working relationship of the plant/animal scientist and the modeler may be tested. After all, the model is not likely to simulate something in the "real world" on first run. The modeler is not likely to be overjoyed when the plant/animal scientist points out error in the simulation model projection, particularly if the modeler knows that a considerable amount of work is required to correct the error. Nevertheless, this is required if data acquired in small-scale short duration studies at the plant-animal interface are to be enlighting and useful.

ORGANIZATION OF GRAZING RESEARCH

Grazing research, as conducted in this country, has been largely fragmented. A principal investigator with perhaps a few graduate students or technicians as support staff and with some "consultant" support from other professionals usually constitutes the available staff. Rarely are the physical resources available more than meager. Yet administrators frequently consider pasture/grazing research as high cost research, even when cattle sales contribute substantially to the fiscal support of the research. The American Forage and Grassland Council with affiliated state councils is doing yoeman work in support of forage and pasture research but the Council's resources are rather limited. The Council can not provide the kind of support provided by other commodity organizations as, for example, Cotton, Inc. in support of cotton research. Forage as silage, hay or pasture is not an ASCS monitored crop, and only limited recognition is given as a cover crop for soil and water conservation. Thus, AES Directors may feel little pressure to support forage and pasture work, even though acreages in pastures and ranges may far exceed cultivated crop acreage in his state.

It appears that frequently the research effort is too scattered. A lone principal investigator is not likely to be as productive as each of three or four principal investigators whose work is organized into a clearly defined team effort. It may be appropiate for those involved in grazing research to suggest the kind of organizational structure required to enhance the productiveness of researchers involved.

In organizing the 1988 CSSA symposium, "Grazing Research: Design, Methodology, and Analysis" it became apparent again that much of the forage/livestock research in this country is done in the states involved in SPFCIC. Thus, it might be useful for the Forage Utilization Work Group along with the Ecology and Physiology Work Group of SPFCIC to take the lead in developing guidelines for an organizational structure that would enhance the productivity of pasture grazing/ utilization research. That sufficient material is available for future workshops on issues in grazing research was evident after a two-day workshop in Lexington in May, 1988.

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ECOLOGY AND PHYSIOLOGY INFORMATION EXCHANGE GROUP

EVALUATING PLANT RESPONSES TO DEFOLIATION: IMPORTANCE, OBJECTIVES AND APPROACHES

J. C. Burns, D. S. Fisher, and K. R, Pond

INTRODUCTION

The value of forages as a human food source resides primarily in its conversion to animal products. The major experimental methods for evaluating the feeding value of forage are grazing trials and animal trials conducted in confinement with conserved forage. Both methods are, in essence, large-scale bioassays. However, the grazing trial, in contrast to trials conducted in confinement, has unique features that are associated with the grazing phenomena.

Interpretation of results from both types of bioassays requires an understanding of plant-animal dynamics. Measurements are required to describe the feed or pasture component, the animal component, and their interaction. Feed and animal interactions, and the experimental description of those interactions, in confined animal studies are less complex compared to when the animal is grazing. The size of the ruminant-animal evaluator in grazing trials requires large experimental units (pastures) and the associated measurements require high labor inputs. In addition, through grazing behavior, the animal (evaluator) has an influence on daily diet quality and the quantity consumed. This diet, which is generally not described, actually becomes the treatment. These, and other factors, place the grazing trial at a noted disadvantage relative to most nutritional and agronomic experimentation. The scale and cost of conducting grazing experiments greatly reduces the number of treatments that can be simultaneously evaluated. In addition, the treatments are not easily specifically defined. Generally, of the many potential forage-animal treatments that might be considered or need evaluation, only a few can be selected and tested. The objective of this paper is to examine the importance of defoliation studies in the evaluation of forages for grazing and to explore methods that can yield useful data.

IMPORTANCE AND NEED

In the past, small plot clipping studies provided data on yield potential and nutritive value. These studies have been viewed by agronomists in forage management as being useful in evaluating the grazing potential of forages. Investigators conducting forage utilization research with a plant science background have recognized the usefulness and limitation of such data relative to grazing experimentation, but tend to ignore factors that effect animal grazing behavior and performance. Investigators with an animal science background have generally ignored small plot clipping studies. The need for defoliation studies in forage evaluation has taken on increasing importance because of an increased awareness of the following: 1) Animals selectively graze green leaf (Arnold, 1981); 2) pasture canopies alter animal grazing behavior (Forbes and Coleman, 1987; Moore, et al, 1985; and Stobbs, 1973); 3) pasture canopy structure may change with herbage mass (Stuth et al., 1987); 4) animals will adjust grazing time as canopy structure and herbage mass is altered (Hodgson, 1982); 5) herbage mass limitations may alter dry matter intake by reducing bite size (Hodgson, 1982) and

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6) ingestive mastication appears specie dependent (Pond et al., 1984) being associated with both plant morphology and maturity which in turn are confounded with canopy structure.

Pasture characteristics and the sensitivity of the grazing animal to them are probably most important when the producer is interested in maximizing daily digestible dry matter intake (DDMI) for high performance. In such situations, forage defoliation studies can provide data that are useful in a grazing setting and they warrant proper consideration. In situations of low performance or near maintenance, many plant characteristics that can potentially influence DDMI are nullified by the animal's grazing behavior and maximization of daily DDMI is no longer of concern. In these cases, plant defoliation studies would be of less value because the data would have less relevance to changes in animal dry matter intake.

The value of defoliation data resides in the extent to which it can be applied to the grazing environment, especially when high producing animals are involved. Consequently, small-plot defoliation studies can be justified only if their overall objectives are to mimic the influence of the grazing animal on subsequent plant responses. This response should include canopy structure as well as growth. An obvious exception would be defoliation schemes which are designed to mimic hay or silage harvesting schedules. Some defoliation studies with objectives directed to turfgrass management may include defoliation intensity and frequencies that have application to grazing. Such studies, however, generally lack data pertinent to grazing such as yield estimates and quality characterization.

Accepting that the proportion of green leaf in the canopy is important in maximizing animal responses, leads to the conclusion that the green leaf component must be easily prehended to maximize DDMI. Ideally, a canopy would produce leaf in sufficient density that the bite size would be maximized and assist in the maximization of daily DDMI. However, bite size may not be of major importance if the animal can compensate with increased grazing time. Understanding how defoliation frequency and intensity of current, improved, or introduced germplasm alters its physiology and morphology, would be invaluable when identifying treatments for grazing evaluation. This holds true for both selecting of the forage species or cultivar and in determining the herbage mass (HM) level or range of HM levels which constitute the treatment(s) for evaluation in the same experiment.

METHODS OF DEFOLIATION

Defoliation of herbage can occur by grazing, cutting, fire, herbicides, treading, drought, frost and wind. The two basic methods of defoliation in experimentation are by mechanical harvesting (clipping) or by grazing. Traditionally, mechanical harvesting of small plots have been the most popular method of examining yield potential and persistence of new or improved germplasm. This approach has been efficient when considering the simplicity and cost of subjecting plants to defoliation stress.

Animals have been used more recently in place of the mower in an attempt to circumvent the artificial nature of intensive defoliation and the removal of all plant material (dead and green) and to examine ingestive behavior. However, investigators must use caution in data interpretation because of individual animal differences and the extent to which results from the few animals that are used can be extrapolated to the general population. A number of different defoliation methods using animals have been tried and are briefly discussed below.

For Preference

Animals may be used to rank germplasm by preference either in the field by grazing (Burns et al., 1988), by harvesting then clipping and feeding fresh in stalls (Burns et al., 1987) or by harvesting, drying and feeding in stalls (Minson and Bray, 1986). The former approach integrates chemical and physical attri-

butes with canopy characteristics as height, morphology and ease of prehension, while feeding fresh in stalls focuses more directly on the chemical and physical properties of the forage. In this case the issue is not how the plant responds to the animal, but how the animal, in general, perceives the plant.

For Plant Response

The main approach for controlling defoliation in grazing studies has been the use of fencing, either conventional or electric. Aluminum gates have also been used instead of fencing (Kalmbacker, 1980) by placing them preceding each defoliation. Also, portable steel pens (5 m x 5 m) in which an animal is retained and the pen moved periodically throughout the day (Burns and Mochrie, unpublished data) have been used as has the tether (Dougherty et al., 1987). These methods all offer a degree of control and the defoliation can be maintained or terminated in a manner consistent with the objectives.

Results from defoliation studies conducted using the mob grazing concept (Ocumpaugh, 1978), in which animals have access to all entries for several days, must be carefully interpreted. In this technique defoliation control for any one germplasm (plot) is relinquished. Consequently, some germplasm can be placed at a disadvantage because of plant characteristics (composition, morphology, etc.) that are either favored by or simply convenient to the grazing animal. Objectives of studies using this approach need to be carefully thought out and clearly delineated.

APPLICATION OF DEFOLIATION DATA

The relative usefulness of one method compared with the other is difficult to assess because neither can truly mimic a continuous grazing situation. Comparison of defoliation effects have been made between or among clipping and grazing (Cuykendall et al., 1966; Matches, 1968, and Taylor, et al., 1960). It is not unusual to have conflicting results from one year to the next, to have a defoliation method x species interaction, or to have disagreement among experiments. Such variation is to be expected because of the many defoliation regimes that can be selected, the inability to totally repeat the same regime with respect to the physiology of the plant from one year to the next, the interaction expected between weather factors and growth, and the wide range of species involved. Consequently, extrapolation of specific defoliation data should be avoided with only the more general characteristics being considered as widely applicable. Little space will be devoted to previous responses, rather the focus will be directed toward the utility of defoliation data.

Because of the way defoliation studies are conducted, the data, unfortunately, are only applicable to rotational grazing schemes. This results from the practice of 1) using a relatively long defoliation interval, as opposed to partial defoliation every few days and 2) defoliating either to a constant stubble height or from a constant canopy height to a differential stubble height.

While the defoliation interval is one factor that negates direct application to continuous grazing, a second is the general harshness of the defoliation action. Mechanical defoliation instantaneously removes the major proportion of the canopy leaf exposing essentially a bare stubble. If clipping occurs below the meristem, the development of lateral or crown buds must occur and consequently a new growth habit is established. This requires the use of carbohydrate reserves as a source of energy until enough leaf area has been regenerated to be self-sufficient. In continuous grazing, only partial tiller removal is likely from any one plant at any one grazing and only part of the leaf area is removed from each tiller. Consequently, few apical meristems would be removed on any one day. Those tillers with meristems removed could begin the process of lateral or crown bud formation while undefoliated tillers continue to elongate providing feed for the grazing animal. Sufficient leaf area remains to maintain a relatively high growth rate essentially independent of root reserves. As few as

10% of intact tillers have been reported to provide adequate photosynthate for growth of tall fescue (Matches, 1966). The view just presented is not, however, totally clear-cut since it would be specie dependent.

Forage species that do not elevate their apical meristem within vegetative tillers and are rhizomatous or stoloniferous, or both, will, under frequent, close mechanical defoliation, generally present a sward that is similar to close continuous grazing. A bunch-type plant, that produces numerous reproductive tillers and which show early elevation of its apical meristem is more likely to be placed at a disadvantage by mechanical defoliation compared with continuous grazing. For example, frequent (every 2 to 4 days) close defoliation of either Kentucky bluegrass (Poa pratensis L.) or bermudagrass (Cynodon dactylon L. Pers.) will result in a sward that is more similar to close continuous grazing than will orchardgrass (Dactylis glomerata L.), or switchgrass (Panicum virgatum L.).

When defoliation studies are conducted using animals as defoliators, some arrangement must be imposed to restrict grazing. While this approach provides plant exposure to grazing action, the degree of defoliation may be exaggerated compared with moderate continuous grazing, and the leaf remaining at the end of defoliation may be much less than in a normal grazing setting. This becomes especially evident when animals defoliating taller canopies are retained in the area to defoliate to a short (5 to 7 cm) stubble height. The animal's adeptness at preferentially selecting green leaf, even from a stubble, becomes evident (J. C. Burns and D. S. Fisher, personal observations).

As with clipping studies, defoliation using animals is generally conducted using a regrowth interval with short-term defoliation (Dougherty, et al., 1987). Although the nature of defoliation by animals, including the animal effects of trampling, excretions, etc., on the forage treatment is desirable, such defoliation tends to resemble mechanical harvesting and the results relate more to rotational than to continuous grazing. Intuitively, controlled use of animals in defoliation studies should provide data more useful in a grazing setting than will mechanically harvesting. Although the choice of one method over another is likely to be decided based on facilities and cost rather than which more closely mimics grazing (either continuous or rotational). In addition to operational aspects are such factors as species, climate, etc. that may affect the application of the data.

MEASUREMENTS IN DEFOLIATION STUDIES

Accepting that defoliation studies should mimic either a grazing setting, or a harvest scheme for stored forage, establishes the general objectives of defoliation research. Special efforts should be made to assure that defoliation treatments are consistent with experimental objectives. Defoliation treatments designed to be intermediate between a grazing and a harvesting schedule and intended to apply to both, will likely apply to neither and be of little value. Also, defoliation treatments selected for ease of defoliation (time and intensity) that are not consistent with the defoliation that may occur in a grazing setting are likely to be of little value. Consequently, the specific objectives will determine the nature of the experiment and will place some bounds on the treatments that should be investigated.

Objectives will be either plant or animal directed or will focus on the interface. The variables measured will then vary depending on the objectives of each study. In addition, the method of defoliation, i.e., by clipping or by grazing, will, by necessity, also be determined by the specific objectives to be evaluated. Measurements that are often useful in specie and treatment selections for large-scale grazing experiments and that can be obtained from small-scale defoliation studies are listed below:

Plant Emphasis

a) Herbage mass pre- and post-defoliation (kg ha^{-1}).

b) Canopy/stubble height (mm).

c) Proportion of leaf, stem and dead (percent).

d) Botanical composition (if applicable) pre- and post-defoliation (percent dry matter).

e) Forage density (kg ha^{-1} cm^{-1}).

f) Growth rate (kg ha^{-1} d^{-1}).

g) Leaf area index.

h) Long-term persistence (plant m^{-1}).

i) Seasonal dry matter production (kg ha^{-1}).

Animal Emphasis

a) Diet quality (IVDMD, g kg^{-1}).

b) Particle size of diet (percent large, medium, and small).

c) Grazing behavior (bites, bite size, chews $boli^{-1}$, etc.).

Interface Emphasis

The study of the plant-animal interface may require any variable listed under "Plant Emphasis" when defoliation is done with animals and all those listed under "Animal Emphasis."

With an interdisciplinary team, it is possible to make all the measurements noted above in one defoliation study. This provides maximum information that could be advantageously used in a grazing setting. Most defoliation studies report only a few of these measurements limiting the value of the total research effort. Physiological measurements that will provide a basic understanding to plant responses to defoliation are considered by Fisher et al., in this publication.

CONDUCTING DEFOLIATION RESEARCH

The specific objectives of defoliation research should be determined by the planned application of the resulting data. The objectives will dictate the experimental design(s) that are useful. Designs should be kept simple to aid in the field aspects of defoliation, whether by mower or by animals, and in the ease of data interpretation. However, a design complex enough to accomplish the objectives must be used. Care must be taken to design experiments with sufficient precision to detect differences when they occur. This requires an adequate number of replications to establish an error mean square small enough, relative to expected treatment differences, to provide a reasonable probability of a significant F-ratio, and sufficient precision to detect differences when they occur. This probably requires a minimum of three replicates and can be estimated prior to experimentation (Table 2.2, Cochran and Cox, 1960).

Determination of the number of replicates is critical because if expected differences between two treatment means does not exceed the confidence interval for the difference, then there is no good reason for conducting the experiment. For example, if a measurement has a coefficient of variation of 6% and the experimenter is satisfied with detecting the difference with a confidence interval of $\pm$ 10% of the mean with a probability of 0.90, then three replicates will suffice. If the desired confidence interval is only $\pm$ 5% of the mean then replications must be increased to nine. The objective of the statistical test is to avoid conducting experiments from which the measurements have no likelihood of being detected as different.

The approach to defoliation research in the past has generally been rather simple with either a defoliation height or frequency defined and maintained throughout the trial. Variables measured under such rigid management may not be the most useful. Consideration should be given to defoliation schemes that include constant as well as variable defoliation treat-

ments. A scheme that might be used with grazing animals is to employ a split-plot arrangement such that, the whole plot of each treatment is sufficiently large (0.25 acre) to permit several splits. If three defoliation intensities were of interest (10-, 17- and 24-cm of growth grazed to a 5-cm residue) then the whole plots could be initially grazed as defined, then the area split for sequential second and third (or more) defoliation cycles with all the initial whole plot defoliations represented within each whole plot on the regrowth. This would result in 27 treatments by the third defoliation which includes a continuously defoliated treatment for each initial defoliation plus each initial defoliated treatment treated differently. Such data would provide an array of plant responses that may be similar to those encountered under grazing. Defoliation treatments that are not meaningful might be deleted.

Incorporating factors such as species, nitrogen application (rate or frequency), etc. into the design allows the examination of interactions that may be of particular interest. Defoliation may occur by either mechanical means or by grazing, depending on the objectives of the study and the available resources.

Application to Continuous Grazing

Defoliation procedures that would provide data that were more applicable to continuous grazing should be examined. This might be achieved by using a plot arrangement (for easy animal movement) that would allow animals to graze a treatment each day or perhaps every other day. The defoliation period would be based on keeping the HM near constant with brief but frequent defoliation. This situation would allow a canopy characteristic of the HM to develop and the treatment can be repeated over time.

Such experiments would have relevance in planning grazing experiments where variable stocking is used and HM can be controlled over time. These results would have much less application where continuous, fixed stocking is practiced because in fixed stocking treatments, HM ranges from year to year and from season to season within a year resulting in the forage treatment being poorly-defined but the stocking rate being well-defined.

Use in Synthesis of Rotational Grazing Systems

Rotational treatments in grazing experiments are difficult to fairly compare because the land area, grazing interval or animals per subdivision should be varied from one defoliation to the next to properly utilize a rotational system. For example, the initial strip allowed in the first defoliation of a specific treatment may have to be increased in size for the second defoliation causing the rest period and subsequent HM within the second strip to be of two different lengths and ages, respectively. This differential may vary among treatments and can be influential on the recurring regrowths. As seasons change, this problem becomes increasingly complex. The treatments then become a flexible array of defoliations based on a set of rules that are not easily defined. Another option would be to adjust animal numbers in subsequent defoliation to coincide with regrowth HM from each previously defoliated strip. This causes difficulty in interpreting animal performance because the diet varies widely in quality and quantity, and consequently the productivity of the system is difficult to estimate.

Results from defoliation experiments in which appropriate measurements are taken may circumvent these problems by providing data that will allow the synthesis of several desirable rotational schemes that are potentially useful in a production setting. Systems synthesized from such data need to be evaluated in a producer's setting. This can take the form of a demonstration and the difficulty of not being able to precisely define or exactly repeat the same sequences from one season to the next or from year to year becomes of less consequence.

ROLE IN FORAGE EVALUATION

Defoliation studies are normally included in forage evaluation protocols (Mochrie, et al., 1980, Mott, 1969). Their inclusion permits examination of both morphological and physiological responses and provides insight into the role the germplasm might fill in a particular production system. Results should be assessed with some predetermined plant characteristic or animal response in mind.

Protocol A (adapted from Mochrie et al., 1980) organizes six phases of evaluation with defoliation by animals being a part of Phase II (Table 1). In this case defoliation studies are viewed in the traditional sense of germplasm evaluation and selection. However, with different objectives defoliation studies can provide base information in the development of grazing systems (Phases V and VI) as previously discussed.

Table 1. Protocol A - a theoretical model for development and evaluation of a new forage.

Plant	Phase	Bioassay
	I	
Collection of material and conception of its potential - agronomic characteristics, productivity, growth patterns and quality (chemical)		IVDMD for quality here and in subsequent phases
	II	
Persistence - geographic (climatic and edaphic), insect and disease resistance, yield and growth response to clipping (simulated grazing)		Animal assessment and influence - preference to assist cultivar selection and quality (intake, esophageal, etc.) estimates and defoliation to determine plant response to grazing (regrowth and persistence)
	III	
Detailed management - stand establishment and maintenance, yield, growth rate and seasonal distribution in response to fertility and clipping routines		Qualitative animal response - daily gains, quality of consumed forage, plant regrowth from and persistence to continuous or intermittent defoliation by animal (preliminary estimate of economic potential)
	IV	
Seed increase or expanded vegetative source		Quantitative animal evaluation - production/ha under management variables and resulting forage quality and response to various defoliation schemes (more extensive economic evaluation)
	V	
Release and on-farm implementation - education of user on establishment and maintenance of stands, observe for possible complications with long term exposure (pests, disease, climate, etc.)		Observation of response to herd or flock utilization - including the development of roles in grazing or feeding systems
	VI	
Refinement and continued improvement - evaluate special management practices (stockpiling, creep feeding, etc.), devise ways to alter distribution of growth, and develop new related genetic material to overcome deficiencies		Refinement - animal response to plant management practices (stockpiling, creep feeding, etc.)

Source: Adapted from Mochrie et al. 1980.

SUMMARY

Grazing or clipping studies provide the opportunity to examine both plant or animal responses to defoliation in a controlled setting. The objectives of these studies should be carefully thought through to determine the method of defoliation (mechanical vs animal) and the frequency and intensity of defoliation. Mechanical defoliation can provide useful information about certain aspects of the grazing environment. The importance of using the grazing animal for defoliation is objective-related and becomes essential if aspects of ingestive behavior, animal diet, and plant x animal interrelationships are important. The use of an interval in mechanically defoliated studies generally limits the application of results to a rotational setting. More consideration should be directed to mechanical and animal defoliated small-plot studies that shorten the defoliation interval (daily) so data will apply to a continuously grazed pasture. Although often not viewed as such, defoliation studies have utility in providing base data for the synthesis of rotational grazing systems. This aspect needs further consideration.

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EVALUATING PLANT RESPONSES TO DEFOLIATION: QUANTIFYING PHYSIOLOGICAL RESPONSES IN CLIPPED AND GRAZED SWARDS.

D.S. Fisher, J.C. Burns, and K.R. Pond

PHYSIOLOGICAL RESPONSES TO DEFOLIATION

Physiological parameters, estimated in defoliation experiments, may help elucidate the mechanisms that result in treatment differences. Understanding the mechanisms of an effect can suggest beneficial modifications of production practices. Modifications should be selected to optimize current and future production of the sward-animal system. Unless mechanisms are understood, the limits and validity of the results will be less certain. Understanding the relationship of a physiological response to environmental and management variables can result in improved production guidelines and recommendations.

The objectives of this manuscript are to examine a few of the ways in which physiological responses and techniques can be utilized to increase the explanatory power of clipping and grazing studies. The focus will be on the role of the plant physiologist as a member of a multidisciplinary team.

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Morphology

In many studies of the effects of defoliation, determination of morphological habit may improve the utility of the data and contribute to understanding treatment effects. Morphological shifts can explain variation between clipping and grazing experiments with similar treatments. The growth habit of some forages may change during the course of the season in response to defoliation. As a result, similar stubble heights may produce dissimilar leaf areas. This may result in differences in regrowth rates between or among treatments.

Individual tiller morphology may provide information useful for estimating the behavior of the whole sward. Observations of tiller initiation, growth, and death can be related to the optimum timing for defoliations.

Indirect estimates of sward morphology may be only correlated with the actual morphology of the sward; for example, percent interception of photosynthetically active radiation (PAR) is correlated with leaf area and canopy structure. Examples of direct estimates of morphology are clipping, stratification, and separation into sward components or determination of leaf angles (Hodgson et al., 1981; Russell et al., 1989).

The selection of an estimator of sward morphology will depend upon the research objectives. It is especially important to match data representing sward morphology to the overall objectives. Using an indirect estimate such as percent interception of PAR will not be of much utility if the relationship of sward morphology to animal diet are of interest. Conversely, if understanding forage regrowth is an objective, it may be important to estimate leaf area, age, and numbers by vertical strata and estimate percent interception of PAR.

Dry Matter Accumulation

Accumulation of dry matter is basic to sward productivity. Estimates of dry matter accumulation vary from annual dry matter yield to net photosynthetic rate per second (NAR). However, many grazing trials have no estimate of dry matter production during the course of the experiment, and many clipping trials have no estimates, other than a mean daily value, of the variation in growth rates between harvest dates.

The estimation of dry matter accumulation should be conducted in a manner that complements the objectives of the defoliation study (Hodgson et al., 1981). Even in trials in which estimates of animal performance are the primary objective, estimates of forage growth can be of value in explaining variation in the animal performance data (Burns et al., this publication). Exclusion cages in continuously grazed paddocks can provide estimates of growth rates as can sequential quadrats harvested in periodically defoliated paddocks.

Estimates of growth do not necessarily require destructive sampling of plots and paddocks. Nondestructive sampling, incorporated with a limited amount of destructive sampling for calibration, provides a viable alternative (Mueller et al., this publication).

If a relative comparison of rates of carbon exchange between treatments is desired, NAR of leaf fragments under controlled conditions may be desirable. If NAR is compared to other estimates of dry matter accumulation such as sequential harvests or exclusion cages, in situ determination of NAR may be more desirable. It may be necessary for certain objectives to sample at multiple times of the day and on leaves representing various classes of leaves. In this case, sampling strategy, given the logistical constraints, becomes a critical design element.

Plant Environmental Stress

Estimating the effects of environmental stresses that occur during the growing season can be of great utility in explaining regrowth following defoliation (Hale and Orcutt, 1987). The interaction of defoliation with environmental stress is of special importance when it differentially affects treatments and results in significant treatment-by-year interactions.

Monitoring the environment should be considered as essential in most defoliation trials. Many researchers are limited to classifying the environment during their studies as wet, dry, warm, or cool. The increased emphasis on combining experimental results and mathematical modeling of forage production will make monitoring and reporting environmental conditions during the course of an experiment even more valuable in the future.

Monitoring physiological responses in the plant is an effective way to test for treatment interaction with environmental conditions. For example, simply estimating canopy temperature can reveal treatment differences in transpiration. Depending on the nature of the defoliation treatment, this could be due to differential soil moisture, differential transpiration at similar soil moistures, or a combination of the two. It may precede observations of decreased productivity (in some grazing trials this may only be inferred from average daily gain or gain per hectare) and indicate areas in which further study could be profitable.

Decreased stomatal conductance can indicate the development of moisture and/or temperature stress and can be used as an indicator of reductions in net photosynthesis. Relatively inexpensive porometers can be used to estimate stomatal conductance.

Reductions in NAR also can be used as an index of plant stress. In addition, some infrared gas analyzer systems estimate stomatal conductance simultaneously with NAR. These systems offer a unique opportunity for study of the effects of stress on photosynthesis. However, care is required to design an adequate sampling procedure to satisfy the experimental objectives, and the variation inherent in pastures presents special sampling problems.

Photosynthetic rates, following various environmental stresses also can be evaluated in the laboratory using leaf fragments in a temperature- and light-controlled chamber with an oxygen probe. This offers advantages over in situ measurement in that it is made under a controlled set of conditions. The decreased sensitivity of the oxygen probe is compensated for by a small chamber and a relatively large change in O_2. These measurements are typically made under saturating CO_2 and light. Additionally, quantum yield curves may be estimated with this apparatus. Shifts in the characteristics of quantum curves may be useful as indexes of moisture stress, temperature stress, shading, and aging. With the appropriate sampling scheme, recovery following stress can also be studied.

Estimates of leaf florescence also have been used as indexes of plant stress (Renger and Schreiber, 1986). Interpretation of florescence data can be controversial; but, if carefully incorporated with measurements of photosynthesis and growth, florescence may provide useful supporting data.

In general, measurements of plant stress will be most important in defoliation studies in which plant growth is a primary focus. Defoliation trials with a focus on animal performance or the plant/animal interface are not generally appropriate for incorporation of stress measurements unless additional data on plant growth also is collected. If the additional data is collected, the experimenter has in effect broadened or redirected the objectives. In most cases limited resources prevent this.

Plant Composition and Anatomy

Changes in plant composition and anatomy directly impact both plant and animal performance. Anatomy is seldom examined in defoliation studies. The logistical problems encountered when doing an adequate job of describing anatomical changes associated with defoliation has been a major obstacle to progress in this area. However, the importance of describing a phenomenon effecting both plant and animal performance dictates that the problems be overcome. The work of Akin (for example, Bohn et al., 1988) has laid a solid foundation for continued research in this area.

Plant composition is frequently examined to estimate nutritional value but in most cases no attempt is made to relate composition to plant growth rates. While, composition may be related to physiological stages such as vegetative, boot, or heading, usually no attempt is made to relate compositional changes to plant growth rates. In some cases the relationship of the environment to composition is examined.

An example of the use of composition in relation to forage physiology is the estimation of carbohydrate content in leaves at dawn and dusk in association with appropriate estimates of NAR and respiration. These data can be used to estimate net carbohydrate export of a specific class of leaves. An intensive sampling schedule is required but can provide needed information on tiller dynamics. The net carbon fixed and exported by a tiller for the day can be estimated in this way.

Root Carbohydrate reserves

The relationship of carbohydrate concentration in storage tissues of forages to persistence and regrowth has received some attention from plant physiologists. However, an aspect that has received little focus is the combination of root and rhizome mass with carbohydrate concentration. The senescence of roots and redistribution of carbohydrate may make depletion of carbohydrate reserves seem less severe than is actually the case. Simply removing a sample of roots from each plot has often yielded results consistent with preconceived notions that grams of carbohydrate per gram of root mass should decline with severe defoliations. Rarely has the root mass m^{-2} or m^{-3} been estimated. More frequently tiller density has been used as an indirect, nondestructive estimation of root and rhizome mass. In addition, early spring growth rates may be related to both root and rhizome density.

VARIATION IN PHYSIOLOGICAL MEASUREMENTS

The importance of designing an appropriate sampling scheme has been mentioned previously. Variation is ubiquitous in defoliation research and especially in studies of grazed swards Variation makes it difficult to achieve accuracy and precision in the estimation of the mean of a sampled plot (paddock) as well as the mean of a treatment.

An awareness of the variation present can be, and should be, incorporated into the design and planning of experiments. This is especially important in constructing a procedure for sampling a plot (paddock). Although the paddock or plot is the experimental unit, most physiological measurements require multiple observations per plot because single observations do such a poor job of estimating the mean. Since only a limited number of samples can be collected, a decision on the most efficient way to allocate the sampling within and among paddocks or plots must be made. Experimental results can be used to estimate variances associated with sampling and experimental error (Gomez and Gomez, 1984). An example of an analysis of variance for percent light interception measured in a randomized complete block is given in Table 1. The error variances are:

$$s_S^2 = MS_1 = 50.98 \quad [1]$$

$$s_E^2 = (MS_2 - MS_1)/n = 2.32 \quad [2]$$

where

MS_1 = mean square for sampling error (see Table 1),
MS_2 = mean square for experimental error (see Table 1),
n = is the number of samples per plot,
s_S^2 = the sampling variance, and
s_E^2 = the experimental variance.

The two variances may be expressed as coefficients of variation by calculating the ratio of their square roots to the mean times 100. These variance estimates may be used to compare the relative magnitude of the two sources of variation. In the example, sampling variance is much larger than the experimental variance. The most efficient use of resources in this case is to take more samples per plot rather than sample more replicates.

Table 1. Anova of percent transmission of photosynthetically active radiation in nine grass canopies.

Source	Degrees of freedom	Mean Square[1]
Replication	2	80.96
Treatment	8	1296.90
Rep by Trmt	16	85.75
Sampling Error	378	50.99

[1] In the text MS_1=50.99 and MS_2=85.75

The estimate of the sampling variance (s_S^2) can be used to calculate the number samples per plot required to estimate the mean with a given level of precision as follows:

$$n=(Z^2*s_S^2)/(d^2*\bar{X}^2) \quad [3]$$

where

Z = standardized normal variate for selected probability level (1.96 for 95% level),
d = accepted error as fraction of mean, and
$\bar{X}$ = mean value.

Since the experimenter frequently decides how many samples to collect based on logistics, rather than statistics, a rearragement to estimate the error as a fraction of the mean follows and may be more useful:

$$d=\sqrt{(Z^2*s_S^2)/(n*\bar{X}^2)} \quad [4]$$

Using equation [4], an experimenter may examine the expected precision (d) on the estimation of the mean with the selected number of samples. If d is too large to be acceptable, then the sampling procedure can be reevaluated. In the example, d was found to be equal to approximately .51 or ±51%. The authors were not satisfied with this and doubled the sample size to 30 to give an estimated d of .36 or ±36%.

IDENTIFICATION AND PRIORITIZATION OF OBJECTIVES

The benefit of working in a multidisciplinary team is hard to overstate and outweighs the many pitfalls (Burns et al., 1988). The increased efficiency and number of variables collected simultaneously should be powerful incentives to the formation and function of team research. One factor that may not be well received by researchers unaccustomed to team research is the identification and prioritization of experimental objectives as a group of scientists rather than as an individual scientist working autonomously. The team works best when each individual is willing to modify at least a portion of their data collection to meet team objectives. Communication within the team is essential so that objectives are clearly stated, worthwhile, and addressed by the data collected.

Forage physiologists have many tools that can be used to expand the utility of defoliation studies conducted by agronomists and/or animal scientists. In addition, the opportunity for physiologists to function in a "real world" setting, while challenging from an experimental design and sampling viewpoint, is invaluable.

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EVALUATION PLANT RESPONSES TO DEFOLIATION: MODELING THE SOIL-PLANT ANIMAL SYSTEM

C.T. Dougherty[1]

ABSTRACT

Simulation models of grazing systems are dependent on logic that quantitatively describes reactions at the plant-animal interface. Models need algorithms to calculate the amount and quality of herbage ingested by the grazing animal from physical and chemical variables that define swards and estimate the effects of grazing on the sward structure and quality, microclimate and the physiology of the regenerating sward.

INTRODUCTION

The objective of builders of simulation models of grazing systems has evolved from a desire to simulate the entire system in exact and correct detail to efficient models that provide appropriate answers to specific questions. Current models of pasture systems contain some modules that truly represent a highly advanced state of knowledge, some modules with simplistic logic, and some modules with no logic at all--the mysterious black boxes. There is always the possibility that critical modules were missing because of oversight or that appropriate logic could not be formulated, perhaps because the knowledge base was limited. Because of subdivision of biology into conventional disciplines, it is not surprising that the logic describing the interfaces between readily identified entities in the soil-plant-animal-atmosphere continuum frequently turns out to be the weakest link in the chain of logic that integrates them (Forbes 1988). The interface between the grazing animal and the grazing horizon of swards is but one example of an area of research neglected for years (Loewer, 1989).

Despite these limitations, models of grassland systems have generally been successful in one objective that has often been used to justify their development. That objective was to encourage research in areas where information was scant and the logic weak. The symposiums devoted to the plant-animal interface at the International Grassland Congress in Japan in 1985, at the annual meetings of the American Society of Animal Science in 1987 and this session meet, at least partially, that objective.

The objective of this paper is to discuss a small segment of activity at the plant-animal interface : sward defoliation by grazing in terms of the logic needed by modelers of grassland systems.

FORAGING THEORY

Grazing behavior of livestock may conform to optimal foraging theory (Stephens and Krebs, 1986). In the monocultures and simple mixtures that account for most managed pastures, logic based on foraging theory assumes that livestock will maximize their intake of metabolizable energy with minimum expenditure of energy in grazing. This implies high rates of herbage intake, minimum grazing times, and conscious selection of diet with high concentration of metabolizable energy. Grasslands composed of herbage species that co-evolved with grazing fiber digesters (Stebbins, 1981) presumably have the capacity, at least some of the time, to optimize energy intake of fiber digesters. Livestock on intensively-managed grasslands, especially monocultures or simple mixtures of grass and legume cultivars, may have the capacity to optimize energy intake on more grazing opportunities than livestock on rangelands.

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Few, if any, simulation models of grazing systems have been knowingly based on foraging theory. We need to establish if foraging theory applies to livestock in managed grassland systems in order to establish a common logic that describes foraging behavior: where, what, and when livestock graze.

DEFOLIATION BY GRAZING

Defoliation by grazing is a complex process dependent on many characteristics of the grazing animal, the sward and the environment. Prehension of the herbage is determined by the structure and activity of the mouth, lips, tongue and teeth and modulated by the eating drive of the animal (Dougherty and others 1987). The techniques used by the grazing animal to grasp and severe the herbage obviously varies with animal species, their age and physiological state. The ingestive process is very much modified by the physical and chemical properties of the sward. In uniform non-limiting swards of alfalfa (*Medicago sativa* L.) cattle graze non-selectively in distinct horizons of 10 to 15 cm achieving high rates of intake but ingestive behavior is moderated drastically as the sward is depleted by grazing (Dougherty and others 1988). The depth of the grazing horizon tends to decline as the sward is grazed down and physical barriers impede prehension and biting. The distribution of herbage by horizontal strata is of interest to modelers of sward growth and grazing.

PHYSICAL BARRIERS TO GRAZING

The identification of physical barriers to prehension and severance of herbage in the process of grazing is probably as important, or more important to modelers, than herbage distribution by strata in grazing. One recently identified sward barrier to grazing is a plane approximated by the tops of pseudostems of vegetative grasses (Barthram and Grant 1984). Pseudostems are the concentrically arranged leaf sheaths of vegetative tillers. In Kentucky summer swards of tall fescue (Festuca arundinacea Schreb.) cattle normally only graze leaf blades above pseudostems and the herbage below 8 cm is largely unavailable (Arias 1988). The pseudostem barrier of grasses appears to be quite uniform in Kentucky cattle pastures one would suspect that it varies in height with management and environment. Obviously pseudostem barriers are much more substantial and effective in swards composed of low populations of old large tillers, conversely, pseudostems of swards composed of many small tillers in pastures maintained at 2 to 4 cm are not likely to be effective barriers say, for sheep. A less well-defined barrier to grazing of alfalfa is expressed as the site of fracture of the stem when cattle complete the herbage-severing action with the characteristic jerk of the head (Dougherty and others 1988). The effectiveness of physical restraints of grazing is lessened for hungry and aggressive grazers (Dougherty and others 1989).

CHEMICAL BARRIERS TO GRAZING

Chemical composition of ingested herbage obviously has direct effects on the grazing process through characteristics expressed in digestion and passage through the gastrointestinal tract. The process of defoliation through grazing is modulated by hunger and satiety and expressed in grazing behavior (rate of intake, intake per bite, rate of biting, and the pattern of grazing meals). In endophyte-infected tall fescue grasslands grazing behavior is moderated, perhaps by alkaloids or ergopeptides (Stuedemann and Hoveland 1988), and the reduction of grazing may account for its adaptation to the grasslands of the transition zone. Endophyte-free fescue pastures tend to be overgrazed in the same ecological niche. Models of tall fescue-based grassland systems offer a difficult challenge to logicians. Other plant chemical constituents may limit or modify the pattern of sward defoliation by grazing and it is not unlikely that some pasture species contain substances that stimulate grazing.

HERBAGE AVAILABILITY

Identification of grazing barriers of swards is essential for the definition of swards for the development of logic that estimates intake and the impact of grazing on swards. If such barriers exist then the logician has a much better handle on the problem of availability of herbage. The fractionation of herbage mass into available and unavailable components should be more useful to modelers than data on dry matter yield above the cutting height that is most common. Most grassland models are based on above-ground herbage mass and the usefulness of much agronomic data is limited because herbage mass below an arbitrary cutting height is not measured. In many swards herbage density increases towards the soil surface and the proportion of stems, senescent and dead material may increase considerably. Unfortunately cutting many swards to the soil surface to obtain this basic data may destroy the sward or severely impact it.

DEFOLIATION BY GRAZING OR CUTTING

Defoliation by grazing is a process that may be quite different from defoliation by clipping or excision of leaves. Regrettably much of our logic is based on defoliation by clipping at a predetermined height such as 5 cm. Mechanical defoliation creates an artificial sward and may create or modify physical barriers to prehension. Mowing of vegetative tillers of cool-season grasses, such as tall fescue below the plane established by tops of pseudostems generates a new barrier to grazing of subsequent regrowth at the mowing height. Thus barriers to prehension may be quite different in swards that were grazed, grazed and topped, or cut for hay or silage. Defoliation is moderated by such factors as herbage allowance, weather during grazing, many aspects of prior management, grazing species and their physiological state (such as hunger-satiety status). Defoliation by grazing is also confounded with the effects of treading and dung and urine on properties of regrowth and subsequent grazing behavior (Wilkins and Garwood 1986).

PLANT ADAPTATION

Ancestors of grassland species coevolved with the ancestors of domesticated livestock (Stebbins 1981) and many widely used cultivars are extremely well-suited to growth under a wide range of management strategies. The widely-used grassland species are quite plastic and adapt to many stresses and situations. Perennial ryegrass (*Lolium perenne* L.), for example, adapts to treading damage and close grazing by stolon development (Korte and Harris 1987). Plant adaptation to grazing and other stresses obviously makes formulation of logic more complex thus favoring grasslands that are intensively managed.

MODEL FLUXES

Dry matter is widely used to describe the fluxes of mass throughout models of grassland systems. The research data from which most logic has been formulated has been based on dry matter yields because of the transient nature of herbage water. Fluxes of carbon, energy, organic matter, digestible components, nitrogen and other components are often concurrently simulated in grassland models. Kentucky research indicates that fluxes of water through the grassland systems should be included in simulation models since sward structure and ingestive behavior may be affected by plant water status. Water fluxes may be essential components of grassland models involving significant levels of water and heat stress of plant and animal components. Models of tall fescue grassland systems would appear to have definite need for water modules.

SELECTIVITY

Selective grazing by livestock is difficult to model since the logic is not well-defined. Selectivity tends to increase when herbage availability and herbage allowances are high and when animals are approaching satiety (Dougherty and others 1989). Grazing livestock prefer leaves over stems, live green tissue over senescent and dead tissue and legumes over grasses. These preferences are expressed in selective grazing of swards if the animal has the opportunity. The expression of selectivity often results in the movement to fresh feeding stations and, as consequence, involves changes in swards within and between feeding stations. These spatial expressions of selective grazing are quite complex and this causes difficulties in formulation of logic and algorithms. Until the logic for selective grazing is established, perhaps by the application of foraging theory, grassland models may be weak in spatial aspects. Conversely, simulation models of managed grassland systems in which selectivity is minimized are likely to be more useful. Some intensive rotational and set-stocked systems eliminate selective grazing by management and are easier to model.

SCALE OF MODELS

The requirements of the models are gross compared with the molecular approach currently favored in biological sciences. The information needed to develop the logic in models of grassland systems is not needed on cellular, organ or whole plant basis but on the basis of surface area of land exposed to solar energy. This limitation is readily accepted by any agronomist who has tried to identify individual plants in a closely grazed sward. It is apparent that any attempt to model individual plants, tillers, or leaves is not warranted in most models of grazing systems. The use of an area of sward as a biological entity fits quite well with concepts such as feeding stations being developed for grazing livestock (Ruyle and Dwyer, 1985).

CONCLUSIONS

Modeling of grassland systems depends on complex logic. Logic that describes the amount and quality of herbage ingested by livestock is essential for the computation of animal productivity. The effect of grazing on the sward is also complex to model especially in grasslands that are not intensively managed. Modeling of grasslands systems that allow the expression of selective grazing are limited by logic that defines spatial grazing patterns. More agronomic research is needed on the physiological responses of grassland species and swards to defoliation by grazing by major livestock species and on the identification of physical sward barriers.

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FORAGE EXTENSION INFORMATION EXCHANGE GROUP

AMAZING GRAZING

J. Paul Mueller
J. T. Green, Jr.

"Amazing Grazing" is a phrase that has been selected to draw attention to a valuable North Carolina resource in the production of meat, milk, and fiber--pasture. Unfortunately, pastures have often been mismanaged and under used. It is now time to realize that this important grassland resource has tremendous potential in keeping cost of production low on most livestock farms in North Carolina.

The whole idea behind "Amazing Grazing" is to keep the attention of livestock producers focused on pasture management. For the past 2-years we have spent most of our educational effort (training sessions, demonstrations, production meetings, etc.) emphasizing grazing management. We believe that people can learn to ration out quality pasture and begin to predict animal performance and production in a way similar to other feeding programs.

Furthermore, we are convinced that our farmers can gain more through the development of pasture/grazing management skills than any other thing relating to forages.

Several demonstrations have shown that cost of beef gain can be less than $.30/lb. One farmer using swine lagoon waste has produced gain for less than $.15/lb. He produced about 1900 lbs of gain/acre/year during the past 2 years. Others have produced more than 500 lbs gain/acre at a feed cost of less than $.35/lb.

In September 1988, 62 county agents indicated that they knew of 550 farmers in North Carolina who had tried some aspect of "controlled grazing" in the past 2 years; seventy-five percent of those farmers were beef cattlemen. A few dairymen have tried small grain pasture and have been surprised to learn that feed costs have dropped and milk yields have remained the same or increased. Research at the Piedmont Station has shown for several years that pasture forage can be substituted for silage or hay and milk yields will remain the same or increase.

While much effort has been spent on teaching agents, industry workers and farmers how to meet animal needs from improved grazing management, several spin-off practices have developed. For example, endophyte testing, soil testing, and feed testing have been emphasized as economical ways to improve pasture and animal management programs. Dairymen who have learned to graze, are often eager to renovate fungus infected fescue, apply fertilizer and manage for clover. Alfalfa, pearlmillet and small grain plantings have increased as a result of people realizing the potential profits from improved grazing management of these high quality crops.

In summary, the current interest in grazing and pasture management is greater than it has been for the past 20 years. This can be partially attributed to the fact that farmers have learned to control forage quality and animal intake by using economical fencing and paying careful attention to animal nutrient requirements during various lactation or production stages. The fact that these practices have resulted in more net profits for many farmers is the final reward.

The Amazing Grazing Program in North Carolina places public awareness on the importance of grassland resources and grazing management. Program materials include: (a) bumper sticker, (b) posters, (c) radio tapes, (d) handbills and demonstrations.

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"CHANGE 3 MILLION" DEMONSTRATION PROGRAM

Joe D. Burns

The Change 3 Million program is an effort to kill the fungus-infected fescue in three million acres of Tennessee pastures and replace it with fungus-free fescue or other crops. Chemical destruction of fescue stands and no-till planting of rotation crops followed by fescue seedings are receiving major emphasis. County Extension staffs, Ag Engineering, Entomology and Plant Pathology, Ag Economics, Animal Science and Plant and Soil Science Sections plus ag industries and Tennessee Valley Authority are involved in this effort.

There have been 10 county demonstrations conducted which show the methods of killing the infected fescue; also the planting of summer rotation crops such as pearlmillets, sorghum x sudangrass hybrids and soybeans and foxtail millet.

There have been three of these demonstrations, Chester, Jackson and Pickett counties, which have planted large scale fescue variety demonstrations of the fungus-free fescue.

Three more, Shelby, Monroe and Greene counties, have planted different varieties of rye, some wheat and a combination of wheat or rye plus ryegrass and crimson clover.

No-till alfalfa has been planted in four counties.

No-till annual lespedeza was seeded in the Lawrence County demonstration, with Sericea lespedeza seeded in Greene County.

Twenty-five counties were sent small plot fescue variety seed packages in the fall of 1988.

Area field days were held in Shelby, Chester (2), Lawrence, Monroe (2), Jackson and Pickett counties with "Change 3 Million" presented on one tour at the Milan No-Till Field Day.

No-till planting has been emphasized throughout the program. A new club is being formed: The Order of the "Fescue Fungus Fighters."

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ALLY: A NEW OPPORTUNITY TO STRESS OLD PRINCIPLES

Bruce W. Pinkerton

Ally is a new herbicide for pastures that is generating high levels of interest because of its ability to selectively remove bahiagrass from bermudagrass pastures. The interest in this chemical has been used to draw many producers to county meetings where weed control has been part of the program, but allowing the overall direction to be aimed at producing quality forages. Clemson has done considerable work with Ally over the last three years. In this paper we will share some of our findings.

For bahiagrass control the optimum time of application appears to be two to four weeks after spring green-up. At this time, one-third ounce of product has typically produced 90+% kill of the bahiagrass while causing no injury to the bermudagrass. Best results have been obtained with at least 20 gallons of water per acre under at least 25 pounds per square inch of pressure. A nonionic surfactant at .25% is absolutely essential. Percent control of bahiagrass has fallen to near zero when no surfactant has been used. Small droplet size appears to be quite beneficial. This is related to the reason that results have been eradic when Ally has been applied in a liquid nitrogen application.

Ally, and the excitement that it is causing is allowing an excellent opportunity to stress proper liming and fertilization methods. The higher the pH the more effective the chemical is. Liming the season before application is optimum. The dead areas created by the bahiagrass will become weedy if the bermudagrass does not have the proper fertility to insure rapid growth to cover the area. This is another reason for early application, that being to let the bermudagrass attempt to cover during its rapid spring growth period and while there are better chances of rainfall. Although, with adequate moisture, Ally activity on bahiagrass is relatively season independent.

Another opportunity to stress older principles under a new cover comes with the percent coverage in the pasture that is bahiagrass. Many of the pastures that will be treated are composed of greater than 50% bahiagrass and will have to be treated almost like newly establishing fields. This offers the opportunity to once again discuss proper grazing management, both of newly establishing fields and of established fields.

It appears that time of application after a field is cut for hay is quite flexible. Application as little as three days after a hay cutting has resulted in over 80% control, or kill, of bahiagrass. Here again is the opportunity to address stage of maturity of forages and its impact on forage quality. The same opportunity exists when discussing the deferment period for grazing or cutting after application. It appears that the bahiagrass requires at least two weeks after application before cutting to insure a good level of control, even though the grazing restriction will be only one day.

Finally, when speaking of bahiagrass control, and weedy invasion of the areas of bahiagrass by crabgrass, the opportunity is presented to speak of the forage value of these two " weeds," and the roles they might play in an overall forage system.

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COOPERATIVE EFFORTS FOR MARKETING HAY

J.N. Pratt, G. D. Lacefield, M. Rasnake, and D.H. Bade[1]

INTRODUCTION

Hay is the only agricultural commodity largly marketed without quality and/or weight guaranteed. And hay quality varies more than quality of any other agricultural commodity.

Traditional marketing of hay has been on sight and smell, as the "clean and green" concept. Much hay is advertised as being highly fertilized, but this claim carries different connotation to seller and purchasers.

Hay and other forage is the number 1 agricultural income simulator in the U.S. In the Southeastern U.S., hay and forage far exceed the value of most other commodities(19). Production of grass hay in Texas is greater than any other state, frequently twice as the next largest producing state.

A review of educational approaches,quality standards, and marketing efforts are presented.

EDUCATIONAL EFFORTS IN HAY QUALITY

Early educational efforts in hay quality were initiated more than 30 years ago in the North and Northeastern states such as, Pennsylvania(2),Wisconsin(12), Minnesota(9), and other areas with high dairy cattle population. These efforts emphasized alfalfa hay and corn silage.

Texas initiated county and area hay shows in 1962(8). Hay days, hay clinics and other educational efforts are sponsored in many states to emphasize quality and to encourage producers to grow better quality hay.

At a typical hay show in Texas(8), producers bring samples to the show (or several days prior to show if laboratory analysis is to be performed). The hay is evaluated on a physical basis and estimates of quality are given for each sample. Forage analyses are valued in the rating. Red, white or blue ribbons are awarded according to a scorecard developed by forage and beef cattle professionals. Ninety county shows are conducted annually, with the State Hay Show a 2 day event - co-sponsored by the Texas Forage and Grassland Council. Some 300 entries, largely grass hays, are evaluated and more than $3,500 value of awards and prizes are sponsored.

QUALITY STANDARDS

Scorecards were developed early and have been acceptable for rapid classification of entries. Table 1 shows the scorecard for classification of Texas hays on physical charcateristics(3). A modified scorecard as a checklist which producers and purchasers can use for rating hay quality has brought favorable response among members of Lake Texana Hay Producers Association(1).

Table 1. Scorecard for classifying Texas hays on physical charcteristics.

Factor	Grass Hay	Legume Hay
Maturity	40	20
Texture (size of stem and pliability)	20	15
Leafiness	10	35
Freedom from foreign material	20	20
Color	10	10
Possible Physical Score	100	100

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Many groups and organizations, such as the American Forage and Grassland Council, National Alfalfa Hay Testing Association, and National Hay Association, have worked together to develop standards for alfalfa based on quality analysis(9).

Table 2 shows the quality standards where the relative feed value (RFV) is based on crude protein, acid detergent fiber, neutral detergent fiber, digestible dry matter, and dry matter intake.

Table 2-Legume, Grass and Legume Mixture Quality Standards.

Quality Standard	RFV
Prime	>151
1	151-125
2	124-103
3	102-87
4	86-75
5	>75

HAY MARKET NEWSLETTERS

In most areas, marketing hay remains traditional. Hay is "sold" rather than "marketed". Educational efforts in recent years have been to incorporate quality and feed value in marketing.

States such as Arizona(15), New Mexico(4) and others provide hay market letters for alfalfa hay. These letters basically report prices of alfalfa hay during the past reporting period.

Oklahoma(13) provides the Hay Market Letter which includes a listing of producers, amounts, and quality of alfalfa hay available. The letter is distributed weekly during the season and throughout the off-season as hay is available.

Texas initiated the "Texas Hay Letter" in 1986(14), which includes market reports and outlook for both alfalfa and grass hays, plus timely tips for producers. The letter is primarily for Extension staff but is avaliable for growers and industry upon request. The letter is issued 18 times per year; twice monthly during the 6 month growing season and once monthly during the 6 month off season.

Indiana(5) provides the "Purdue University Hay Locater" which is a computer listing of growers with hay available for sale.

The Texas Farm Bureau provides a listing service for $5.00 per grower. This service is updated weekly and is available through participating county farm bureau offices.

Several counties in Texas such as Smith County in East Texas and Lee County in South Central Texas periodically provide a listing of growers with hay for sale.

MOBILE LABORATORIES

With the advent of reliable, rapid forage analyses, hay marketing efforts have escalated. The NIR procedure of evaluating alfalfa has been widely accepted. Within the past 10 years, states such as Pennsylvania, Wisconsin, Minnesota, Texas and others have adopted the NIR analysis for hay quality. NIR/computer programs for alfalfa are satisfactory. Texas has developed programs for bermudagrass and bahiagrass(10).

Wisconsin initiated mobile forage testing by installing the instruments in a van and taking the laboratory to the growers. Minnesota has worked with Wisconsin and has provided leadership for certifying laboratories for accuracy and analysis. Other states such as South Dakota are using the van and portable laboratory seasonally during the year.

HAY AUCTIONS

Using the NIR van for portable, rapid analyses, hay growers and professionals initiated hay auctions. The basic concept is that growers bring their samples (or a lot) to a designated location. The samples of hay are collected and analyzed at the site. Usually the hay arrives before 11:00 a.m. and analyses are completed immediately. The relative feed value (RFV) is posted on each lot. The auctioneer moves along the yard with a portable microphone and auctions each lot.

Hay auctions in Minnesota(9) have done more for the county educational program than all other activities in the past 25 years. The main function of the auction is that growers and others interested in hay get together several times during the season. Their conversations includes hay quality, varieties, fertilization, liming, and other practices for hay production and utilization.

Wisconsin results(12,17) show that hay sells for higher prices when the weight and quality of hay is known. Although only 5% of hay marketed in the state is sold through the auction, growers and buyers use the auction prices for establishing their contracts. Of 1807 lots of hay marketed on quality standards for 2 years through hay auctions in Wisconsin, the prime grade sold for $38 and the No.1 hay sold for $24 per ton more than the No.2 hay, Table 3.

Table 3. Average Price/Ton By Grade in Wisconsin Quality Tested Hay Auctions (2 year ave 1807 lots)

Grade	Maturity	Price/Ton
Prime	Bud	$117
1	E.Bl.	103
2	M.Bl.	79
3	F.Bl.	68
4	P.Bl.	65
5	*	63

HAY PRODUCERS ASSOCIATIONS

In 1986 hay consumers in Brazos County, Texas organized the Brazos County Hay Producers Association. The primary objective was to emphasis hay available on weight and analysis. The by-laws call for the association to be educational rather than marketing. BAHPA provides a directory of growers with hay available. At least 4 educational activities are conducted each year: A Forage day in June or July, the County Hay Show, a Winter Pasture Clinic, and Hay Auction.

Also in Texas, the Lake Texana Hay Producers Association was organized to emphasis hay quality. The by-laws express the organization is to be educational.

MARKETING COOPERATIVES

The Kentucky General Assembly appropriated money in 1988 for the Department of Agriculture to "promote the sale of hay produced in the state operating, maintaining, and administering a standard grading program for evaluating hay". During the first year, they have developed the standards for hay grading, purchased three Near Infrared Reflectance Spectroscopy (NIR) forage analysis instruments and set up a system for sampling and testing hay. A fee of ten dollars is charged for sampling and testing each lot of hay. They will not be directly involved in the sale of hay.

At the same time, a statewide hay advisory committee of about fifty people was formed and charged to plan and develop a system for marketing Kentucky hay. The system developed was a state-wide hay marketing cooperative. The committee drew up temporary by-laws and directed the selection of an interim board of directors. Eventually, each of fourteen areas in the state will be eligible to form area cooperatives and elect one representative to the state board, thus replacing the interim board.

The cooperative was set up as a non-profit corporation. The interim board met in December, 1988 and approved the Articles of Incorporation and By-Laws. In May of 1989, Bowling Green was selected as the site for the office headquarters. An executive director was hired and began work in June 1, 1989. individual memberships are being solicited with dues set at $25.00 per year. Only members are permitted to sell hay through the cooperative.

Members who have hay for sale call to have the hay sampled. The hay is sampled and physically described by an employee of the Department of Agriculture. The sample is analyzed for dry matter, crude protein, acid detergent fiber, neutral detergent fiber, calcium, phosphorus, magnesium and potassium. Calculations are made for heat damaged protein, available protein, digestible protein, total digestible nutrients, estimated net energy, feed and value. In addition a "Triple Crown" designation will be given to hay that meets extremely high standards for color, lack of dust or mold, and freedom from foreign materials. This is designed for the horse industry.

Producers store their hay and make provisions for truck access and loading. The cooperative sells the hay, guarantees the quality, collects payment for the purchaser and pays the producer. A small percentage of the purchase price is withheld to cover expenses of the cooperative.

SUMMARY

Progressive hay producers and purchasers are recognizing differences in hay quality and are purchasing hay based on quality and weight.

Extension educational efforts emphasizing forage quality and value differences such as, hay shows,forage testing, and plant analyses, have been effective for creating producer and purchaser awareness of quality.

New laboratory analyses are rapid and reliable with instrumentation such as NIR and ICP.

Surveys of growers participating in mobile laboratory analyses show that these growers are more likely to use forage testing in future seasons.

Hay auctions are becoming popular in areas where mobile vans or other methods are available for rapid analyses and reporting.

Extension forage Specialists need to take the lead in hay marketing to show producers/purchasers the value of hay analyses and bale weights.

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FORAGE IN-SERVICE TRAINING FOR EXTENSION AGENTS IN THE SOUTHEAST

Dr. Monroe Rasnake and Dr. Troy Johnson[1]

The information presented in this paper is based on a mail survey of extension forage specialists in twelve southeastern states. Eight of the twelve responded to the survey. Those were in Tennessee, Virginia, West Virginia, Alabama, Mississippi, Arkansas, Georgia and Kentucky. The methods reported by these eight are varied and probably encompass those used by the other states. We will discuss how in-service training is planned, coordinated and conducted by each state.

Tennessee conducts a two day, in-depth "Forage Production and Utilization" program every four years. It is planned and coordinated by extension agronomy specialists, but utilizes specialists from other departments to assist in the training. The training is offered at three locations across the state. There is also an annual one-day update session coordinated by the Plant and Soil Science Department. Forage training is presented during one thirty minute session. This is conducted for each of the five extension districts in the state. In addition, forage topics are often included in training sessions conducted by other departments such as Animal Science, Veterinary Science, etc. Tours of on-farm demonstrations are frequently a part of agent training sessions.

Virginia has a very regimented system for agent training. The Extension Division schedules a week in January each year for agents to come on campus for training. In August, teams of extension specialists develop lists of suggested topics that they feel are timely and important for agent training. Agents also develop lists of topics they feel are needed. These are submitted to area program leaders who select the topics to be included in the training program. Forage topics are nearly always included in the program. In 1988 and 1989, forage topics occupied one whole day.

In West Virginia, extension specialists prepare course outlines to be included in agent training. These are distributed to the agents and they select the ones they would like to have. Course offerings are based on how many agents sign up for them. Special short courses are sometimes offered for graduate credit based on interests expressed by the agents. These are used by the agents as credits toward a Masters Degree. Extension specialists develop audio-visual materials to assist agents in educational programs with producers. They are not designed as training materials for the agents themselves.

Formal in-service training in Alabama is closely coordinated by the College administration. It ranges from one day "agronomy update sessions" in which forages might occupy one hour to one or more full days involving just forages. At least some training in forages is included every year. Videos, field tours, movies, etc. are used for agent training. Many of these materials are provided to the agents prior to the training sessions. Some agents are asked to help with the training sessions. Sometimes, they are divided into teams which compete against each other.

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All new agents in Mississippi are required to participate in a basic, in-depth training session on forages. This is conducted by extension specialists in a formal classroom setting. Annual update training sessions on forages are conducted for established agents. These usually involve a half day in the classroom and a half day of training in the field. Specialists prepare course outlines for the College administration and for use by the agents.

Agent training in Kentucky is not coordinated by the College administration. Individual specialists or more often groups of specialists plan and schedule training sessions. Dates, locations and outlines are prepared and given to administrators. Sessions are scheduled throughout the year and usually in two or more locations in the state. These are publicized with the agents and they choose which ones they want to attend. Some forage training is often included in these sessions. However, most forage training consists of agents participating in major forage meetings open to the public. Examples are an annual forage conference in January and annual alfalfa conference in February or March. The topics and locations of the conferences change from year to year. Most agents attend and bring along some of their best producers.

A major tool in training agents in forages in Arkansas is the "Verification Farm". This is used to give agents hands on training with approved techniques and new ideas in forage production. The farms are planned and directed by a team of extension and research specialists. The agent in the county where the farm is located is part of the planning team and helps with the day-to-day management. Other agents are brought to the farm in groups for training.

Specialists in Arkansas also plan and conduct classroom-type training sessions. The meetings are publicized with the agents and they choose which ones they will attend. These are not coordinated by the College administration. Correspondence courses in forages have been developed and offered to agents and producers. These are not offered for college credit at this time.

Formal agent training in Georgia is coordinated by the subject matter specialist and the District Agent for Agriculture. Specialists develop and submit training proposals through the administrative chain. Most agent training is interdisciplinary involving animal science, dairy science, and frequently other disciplines. Normally, training is scheduled for one full day; however, recent proposals for two-day sessions involving several departments have been favorably received. New agents receive one week of intensive training each year for the first three years. Forage training is a part of the scheduled training. Informal agent training is conducted through area and county meetings, field days, and publications.

In summarizing, there are several trends in agent in-service training which came out of the survey:

1. Administrative coordination varied from almost none to total.

2. Methods varied from observations in the field to classes for graduate credit.

3. All felt that in-service training was important.

4. All offered some training on an annual basis.

MINUTES OF THE BUSINESS MEETING

45th Southern Pasture and Forage
Crop Improvement Conference
Little Rock, Arkansas
June 14, 1989

The meeting was called to order by Chairman, Werner Essig. The following items were acted upon:

Old Business

1. Minutes of the 44th meeting have been published in the Proceedings and a motion was made to dispense with the reading of these minutes and accept them as published. Motion made by Henry Fribourg, seconded by Bill Brown. Motion passed.

2. A treasurer's report was made indicating a June 5, 1989 balance of $6,496.84. Motion was made by Ken Quesenberry, seconded by Lance Tharel to accept the reading as information. Motion passed.

3. A report was made concerning the disposition of excess SPFCIC funds. An ad hoc committee consisting of Jerry Matches, Bill Stringer, and Jim Green recommended that the excess money be invested and the interest be used to support graduate student travel to SPFCIC meetings. However, it was mentioned that the executive committee on June 12, 1989 had recommended no action because of problems in dispensing such a small amount equally. A motion was made by Don Ball and seconded by Monte Rouquette to accept the recommendation of the Executive Committee: No action. Passed.

New Business

4. The annual publication of a SPFCIC directory was discussed. A motion was made to contact individuals in each state who would supply names, addresses, and phone numbers of all people who would be interested in SPFCIC meeting content. These names, etc. would be pooled and published and dispersed to potential participants. Motion made by Nick Hill, seconded by Marvin Riewe. Passed.

5. Monte Rouquette explained the Texas program for the 46th annual meeting.

6. A letter of invitation by Dr. Rodney Foil of the Mississippi AES was read by Bill Brock. The letter welcomed SPFCIC to hold the 47th meeting in Mississippi in 1991. A motion was made by Ken Quesenberry to accept the invitation, seconded by Carroll Chambliss.

7. The recommendation of the nomination committee, which consisted of B. J. Hankins, Lance Tharel, and R. Joost (LSU) who recommended Dr. John Stuedemann as chairman-elect. A motion was made by David Bransby to close nomination and accept the recommendation of the nominating committee.

8. Two resolutions were read by R. S. Kalmbacher. The first recognized Dr. O. C. Ruelke, retiring from the University of Florida, and the second resolution recognized the work done by the Arkansas group to conduct the 45th meeting. Both resolutions are attached. Motions were made and seconded for each resolution.

9. The gavel was passed to R. S. Kalmbacher, Chairman for the 46th SPFCIC. After presenting Werner Essig with a plaque, a motion was made, seconded, and passed to adjourn the meeting.

Respectfully submitted,

J. PAUL MUELLER
Acting Secretary
SPFCIC

RESOLUTION ADOPTED UNANIMOUSLY BY THE 45TH ANNUAL SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE, LITTLE ROCK, ARKANSAS
June 14, 1989

WHEREAS, the membership of the 45th Annual Southern Pasture and Forage Crop Improvement Conference has gleaned much information and great benefits from its participating in the conference, and

WHEREAS, such information and benefits could not have been realized without the friendly, hospitable and concerted efforts of the staff and administration of the University of Arkansas.

BE IT RESOLVED that the 45th Conference expresses its grateful appreciation to the staff, faculty and administration of the University of Arkansas for their gracious hospitality, imaginative programming, well planned and executed tour, which was of interest to the membership, and

THAT special recognition be extended to Dr. G. J. Musick, Dean for the School of Agriculture and Director of the Experiment Station, the following individuals who served on the local arrangements committee: Drs. Chuck West, Cliff Snyder, Lance Tharel, Stan Chapman, and Mike Phillips.

TO OUR HOSTS Mr. Ed Martsauf and others at the Heifer Project International, Mr. Robert Carruthers, farmer from Morrilton, AR.

TO Conference Chairman, Dr. Werner Essig, Immediate Past Chairman (and Program Chairman), Dr. Don Ball, Acting Secretary-Treasurer Dr. Paul Mueller.

TO Session Chairman Jorge Mosjidis, Lance Tharel, Lynn Sollenberger, and B. J. Hankins.

TO all who presented conference papers.

1989 Resolutions Committee

R. S. KALMBACHER, Chairman
B. J. HANKINS
L. E. SOLLENBERGER

RESOLUTION ADOPTED BY THE 45th
SOUTHERN PASTURE AND FORAGE CROP
IMPROVEMENT CONFERENCE
Little Rock, Arkansas
June 14, 1989

WHEREAS, Otto Charles Ruelke has participated in the Southern Pasture and Forage Crop Improvement Conference for more than 36 years, serving as Chairman in 1964, and

WHEREAS, he has served with distinction to solve many problems with forage management, and

WHEREAS, he has devoted his life to teaching and training more than 3,000 students over the years,

BE IT THEREFORE RESOLVED that we recognize our friend and professional colleague, Dr. Charlie Ruelke, and thank him for his many contributions to the improvement of grasslands in the Southeast and wish him many years of happiness during retirement.

1989 Resolution Committee

R. S. KALMBACHER, Chairman
B. J. HANKINS
L. E. SOLLENBERGER

FINANCIAL STATEMENT
1988-1989
Southern Pasture and Forage Crop
Improvement Conference

Presented in Little Rock, Arkansas
June, 1989

	Income	Expense	Balance
05/04/88 Balance on hand at Wachovia Bank and Trust Account #6261 206760			$6,162.27
05/11/88 Expenses for Grazing Methodology Workshop - Radison Plaza, Lexington, KY		$227.30	
05/16/88 Income from Grazing Methodology Workshop, Lexington, KY	$234.00		
10/04/88 Refund of Post Office Permit from Watkinsville, GA	$202.82		
12/01/88 Postal Account in Beckley, WV (David Belesky)		$300.00	
03/21/89 Interest credited to account for period 04/07/88 to 03/06/89	$348.05		
03/21/89 Balance on hand			$6,419.84
05/08/89 Plaque Expense, W. Essig		$30.01	
06/05/89 Interest credited to account for period 03/07/89 to 06/05/89	$107.31		
06/05/89 Balance on hand			$6,496.84

Respectfully submitted by J. Paul Mueller for James T. Green, Jr.

MINUTES OF THE FORAGE BREEDERS INFORMATION EXCHANGE GROUP

Dr. Jorge Mosjidis called the business meeting of the Southern Forage Breeders to order. Under old business, Dr. Everett Emino, the administrative advisor to the forage breeders work group, provided an overview of the SRIEG-11, and informed the group that the Board of Southern Experiment Station Directors had extended their approval for the Southern Forage Breeders to meet annually until 1993. Dr. Emino also encouraged an active participation by all forage breeders (SAES and USDA-ARS) within the Southern Region at these meetings.

Under new business, Dr. Mosjidis informed the group that Dr. Baltensperger (Chairman, SRIEG-11, Southern Forage Breeders) had accepted a position in Nebraska, and that the Southern Forage Breeders would be without a program chairman for the 1990 meeting to be held in Texas. Discussion followed and a motion was made by Dr. Quesenberry and seconded by Dr. Pederson that the chairman and secretary for the 1990 meeting handle the responsibilities of program chairman. The motion was approved.

Election of New Officers:

Dr. Hussey nominated Dr. G. R. Smith (TAES-Overton) to be secretary for the 1990 Southern Forage Breeders Workgroup Meeting. Dr. Pederson seconded the motion and the motion was approved. Officers for the 1990 meeting to be held in Texas will be as follows:

Program Chairman: vacant*
Chairman: M. A. Hussey, Texas A&M University
Secretary: G. R. Smith, Texas Agricultural Experiment Station, Overton, TX

*Drs. Hussey and Smith will share the program chairman duties for the 1990 meeting.

Before the meeting was adjourned, Dr. Austin Campbell (USDA-ARS, Beltsville) mentioned the need to obtain rust samples from alfalfa. Anyone having such samples should contact Dr. Campbell in Beltsville.

With no further new business, the meeting was adjourned.

MINUTES OF THE FORAGE UTILIZATION INFORMATION EXCHANGE GROUP

The meeting was called to order by President Lance Tharel at Little Rock, AR on June 13, 1989. A tablet was circulated for those in attendance to record their names, addresses, and suggestions of topics for future meetings.

A motion was made and seconded to dispense with the reading of the minutes of the 1988 business meeting held in Lexington, KY.

The nominating committee, chaired by Stephen P. Schmidt, presented Monte Rouquette. Texas A&M Agricultural Research and Extension Center at Overton, TX as Secretary-Elect. He was unanimously elected. Stephen P. Schmidt will serve as president for the next year.

The motion was made and seconded to dispense with introductions of the individuals in attendance.

Stephen P. Schmidt asked if there were any comments or further suggestions on topics for the future and read those topics already recorded. Lance Tharel pointed out the utility of the suggestions in formulating the programs for the work group.

The motion was made and seconded to adjourn.

MINUTES OF THE EXTENSION INFORMATION EXCHANGE GROUP

The meeting was called to order by Extension Work Group Chair, Dr. Bruce Pinkerton. The first item of business was to nominate and elect new officers for the coming year. Discussion centered on the fact that since the 1990 meeting would be in Texas, it would be logical to have someone from Texas to serve as Program Chair. Consequently, Dr. Sim Reeves was nominated and elected by acclamation.

In addition, since tradition holds that the Secretary should be from the state where the SPFCIC will be held two years hence, Dr. Lamar Kimbrough will be the secretary in 1989. In similar fashion, Dr. B. J. Hankins will move from Program Chair to Chair of the Extension Work Group.

Session Chair Pinkerton asked if there was additional business and there was none. He thanked the Arkansas representatives present for their efforts in arranging a very worthwhile Conference, including the Extension Work Group Session. Subsequently, the meeting was adjourned.

MINUTES OF THE ECOLOGY AND PHYSIOLOGY INFORMATION EXCHANGE GROUP

The meeting was called to order by Dr. Richard Joost at 11:45 a.m. on June 13, 1989. Dr. Joost announced the current officers of the group: Dr. Lynn Sollenberger (Univ. of Florida, Program Chair for the 1989 meeting), Dr. Richard Joost (LSU, Chair), and Dr. Chuck West (Univ. of Arkansas, Secretary). The Chair then opened the floor for nominations for Secretary of the group for 1989-90. Chuck West (Univ. of Arkansas) nominated Dr. Wink Alison (LSU). The motion was seconded and Dr. Alison was elected by acclamation. A questionnaire was circulated asking for suggestions for future program topics. The meeting was adjourned at 12 noon.

The following is a summary of responses to the request for topics:

Participant	Suggestion
W. C. Stringer	Effect of the Tall Fescue Endophyte on Pasture Ecology
C. West	Roots, Nutrient Cycling, Phenology, and Growth Stage Systems
M. Eichhorn	Nutritional Effects of Minerals on Forage Digestibility
G. Brink	Legume (White Clover) Ecology, Pasture Ecology, and Plant Response
W. E. McMurphy	Methods of Evaluating Forage Legumes for Pasture Use
D. Kee	Effects of Nutrient Supplementation to Animals on Soil Fertility Changes in Perennial Pastures
M. L. Dahmer	Plant Responses to Abiotic Stresses
G. Evers	Annual Clover Persistence (Seed Production, Hardseededness, Summer Germination, Grass Competition, Establishment)

SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE EXECUTIVE COMMITTEE 1990

Executive Officers

Rob Kalmbacher	Chairman
Kenneth Quesenberry	Chairman-elect
John Stuedemann	Chairman-elect-elect
Werner Essig	Immediate Past Chairman and Program Chairman for 1990 (46th Meeting)
Jim Green	Secretary-Treasurer
Mark Hussey	Breeders Work Group Chairman
Richard Joost	Ecology-Physiology Work Group Chairman
B. J. Hankins	Extension Work Group Chairman
Steve Schmidt	Utilization Work Group Chairman
Dave Belesky	Proceedings Coordinator

Officers of the 1990 Work Groups

Breeders Work Group

Mark Hussey	Chairman and Program Director
G. R. Smith	Secretary
David Baltensperger	Past Chairman

Ecology and Physiology Work Group

Richard Joost	Chairman and Program Director
Chuck West	Secretary
Lynn Sollenberger	Past Chairman

Extension Work Group

B. J. Hankins	Chairman
Sim Reeves	Secretary and Program Director
Bruce Pinkerton	Past Chairman

Utilization Work Group

Steve Schmidt	Chairman and Program Director
Dwight Fisher	Chairman-elect
Monte Rouquette	Secretary-elect
Lance Tharel	Past Chairman

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